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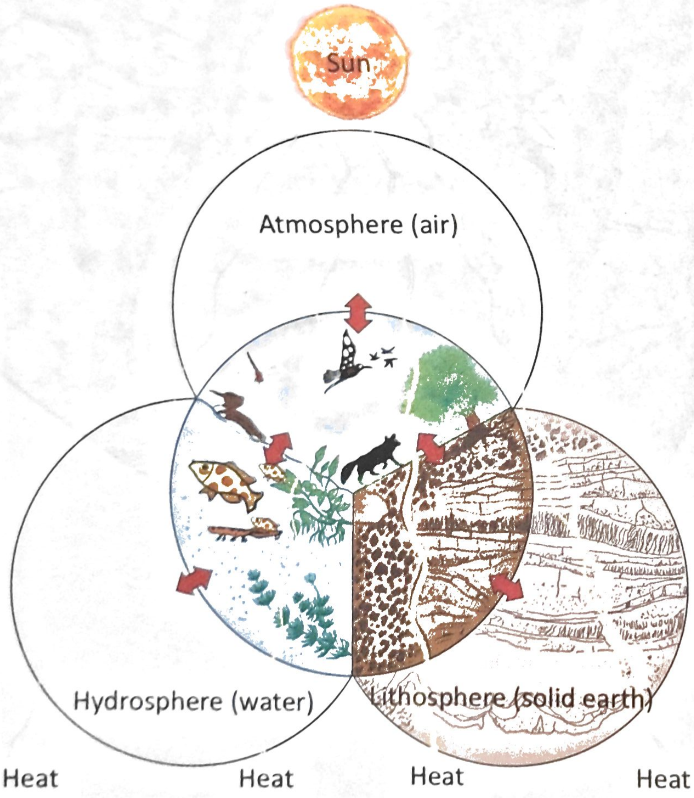
INTRODUCTION TO ENVIRONMENT AND ECOLOGY

The Earth is a diverse planet consisting of four major **systems or "spheres".** These systems are interconnected and influence each other. Together, these systems make life possible on Earth. Changes in one system can affect each other and the Earth as a whole.

The four major systems of Earth are:

- **Lithosphere:** Also known as geosphere, it is the solid outer part of the earth. It consists of rocks, sediments and soils, different types of landforms and the processes that shape the surface.



Different Spheres of Earth

- **Atmosphere:** It is the envelope of gas surrounding the earth. It includes meteorological features such as weather and climatic conditions, clouds, aerosols etc.
- **Hydrosphere:** It includes water on or near the earth's surface. This includes oceans, rivers, lakes, ponds, groundwater. The frozen water part of the earth system is known as **cryosphere**. It includes snow and ice on land, ice caps, glaciers, permafrost, and sea ice.
- **Biosphere:** The part of the earth that supports life is known as the biosphere. The word biosphere has its origin in the Greek word "bios" meaning life and the Latin word "Sphaera" meaning "circuit or range of action" or the "place of action or existence". The biosphere includes all living matters (such as plants, animals, microorganisms) and exist in the geosphere and the hydrosphere.

ENVIRONMENT

Everything that surrounds and affects an organism is called environment. The term "environment" is derived from the French word 'environner' meaning to encircle or to surround. Environment includes both biotic (living) and abiotic (non-living) components.

The environment provides living organisms all the necessities to survive- the food to eat, water to drink, air to breathe and shelter. Thus, it is rightly called the **"Life Support System".**

Types of Environments

Environment can be classified into two different types viz. Natural Environment and, Human (man-made environment).

Natural Environment: It includes all the biotic and abiotic entities that exist naturally. For example, forests, deserts, grassland, pond, lakes etc. Let us take an example of fish in a pond. Different abiotic factors such as light, temperature, nutrients etc. and other organisms like insects, bacteria, aquatic vegetation form the natural environment of a fish in the pond.

Human (Man-made environment): It is the environment created by humans. Humans interact with the natural environment and modify it according to their needs. Examples include cities, towns, industries etc.

ECOLOGY

Ecology is the scientific study of inter-relationship and interaction of different organisms with each other and with their environment. Ecologists study how living things interact with each other and with non-living things such as air, water, and soil. The word 'ecology' is derived from the Greek words 'oikos' and 'logos', oikos meaning 'household', place to live' or 'habitation', 'logos' means, 'study' or discourse'.

In 1866, the German zoologist, **Ernst Haeckel** coined the Ecology. He used the term to describe the "relation of the animal both to its organic as well as its inorganic environment."

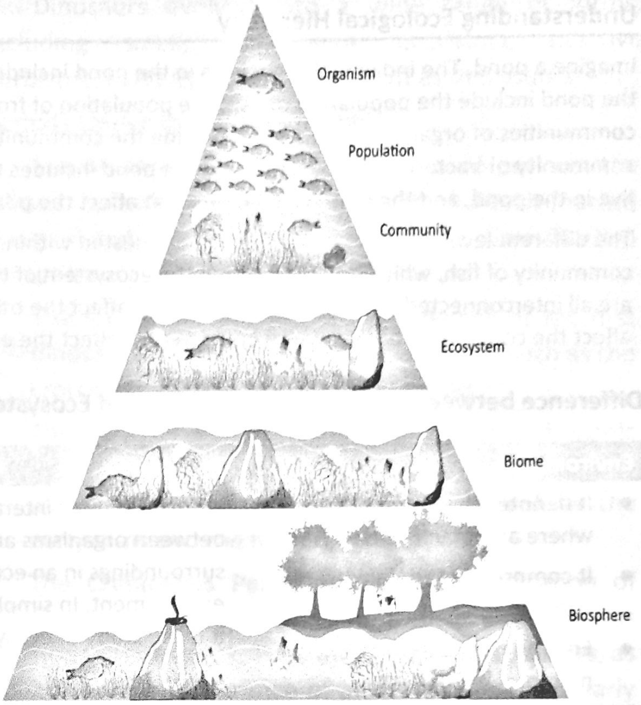
Types of Ecology

Different types of ecology focus on different aspects of the natural world. The main types of ecology are as follows:

- **Population Ecology:** Also known as autecology, it is concerned with understanding the interactions between individual organisms and their environment. It also studies how these interactions affect the overall population.
- **Community Ecology**: Also known as synecology, it is concerned with the study of the interactions between different species living in a particular ecosystem.
- **Ecosystem Ecology:** It focuses on the study of entire ecosystems. It studies both the biotic and abiotic components.
- **Landscape Ecology:** It focuses on the study of the spatial patterns and relationships between different ecosystems.
- **Behavioral Ecology**: It studies the behavior of individual organisms, and how it affects their interactions with other organisms and their environment. It seeks to understand how organisms make decisions about foraging, mating, and social interactions.

Ecological Hierarchy

At its core, ecology is concerned with understanding the organization of life on Earth. It studies the organization through the Ecological hierarchy theory. The theory describes the arrangement of biological organisms in relation to one another. The different levels of organization in ecology are as follows:



Levels of Organization in Ecology

- **Organism**: It is the first level of organization. It refers to an individual organism. For example, a single tree, a single animal etc. At this level, ecologists study how organisms interact with their environment.
- **Population:** The term population denotes all the members of the same species that live in the same place at the same time. At this level, ecologists study how populations of organisms interact with each other, including competition for resources and reproductive behavior.
- **Community**: It refers to all the different populations of organisms living in the same geographic area and interacting with each other.
- **Ecosystem:** It includes the living organisms (biotic) in an area and the non-living aspects (abiotic) of the environment. For example, a single lake, a forest etc. At this level, ecologists study flow of energy and nutrient cycling in an ecosystem.
- **Biome:** It is the largest geographic biotic unit. It includes a major community of plants and animals with similar life forms and environmental conditions. Example: Tundra Biome, Desert Biome, Taiga Biome etc.
- **Biosphere:** It is the part of the earth with living organisms. At this level, ecologists study the global cycles of carbon, nitrogen, and other elements. They also study how these cycles are influenced by human activities such as fossil fuel burning and deforestation.

Understanding Ecological Hierarchy

Imagine a pond. The individual organisms in the pond include fish, frogs, algae, and bacteria. The populations of organisms in the pond include the population of fish, the population of frogs, the population of algae, and the population of bacteria. The communities of organisms in the pond include the community of fish, the community of frogs, the community of algae, and the community of bacteria. The ecosystem of the pond includes the pond itself, the water in the pond, the plants and animals that live in the pond, and the non-living factors that affect the pond, such as sunlight, temperature, and water quality.

The different levels of ecological hierarchy are nested within each other. For example, the population of fish is nested within the community of fish, which is nested within the ecosystem of the pond. This means that the different levels of ecological hierarchy are all interconnected. Changes at one level can affect the other levels. For example, if the population of fish decreases, it could affect the community of fish, which could in turn affect the ecosystem of the pond.

Difference between Environment, Ecology and Ecosystem

Environment	Ecology	Ecosystem
• It denotes the surroundings where an organism lives. • It comprises of the physical components. • Environment can be micro or macro.	• It is the study of interactions between organisms and their surroundings in an ecosystem or environment. In simplest terms, it is the study of ecosystems.	• It is an ecological unit which includes all the organisms living in a particular area and all the abiotic features of the local environment. • It is the functional unit of the environment. • A group of ecosystems form an environment. • It can be a terrestrial or aquatic ecosystem.

Evolution of the Biosphere

The biosphere, which encompasses all living organisms on Earth and their interactions with the environment, has evolved and changed over billions of years as evidenced by the fossil record and other geological evidence.

The biosphere experienced significant diversification of life forms over millions of years through processes like natural selection, genetic mutation, and speciation. Different forms of life, including plants, animals, fungi, and protists, evolved and adapted to various environments on Earth, leading to the establishment of complex ecosystems.

Evolution in Brief:

Single cellular → Multicellular → Fishes → Amphibians → Reptiles → Birds → Mammals.

Precambrian (4.6 billion years ago - 541 million years ago):

The Precambrian is the longest and oldest eon in Earth's history.

During the early stages of Earth's history, the biosphere was dominated by prokaryotic microorganisms, such as bacteria and archaea. These simple organisms lived in the oceans and played a crucial role in shaping the early Earth's atmosphere through processes like photosynthesis, which released oxygen as a by-product.

Eons under Precambrian

It is divided into three main eons: the Hadean, Archean, and Proterozoic.

Hadean Eon	Archean Eon (Origin of Life: Evolution of Prokaryotes)	Proterozoic Eon (Emergence of Eukaryotes)
During the Hadean eon, the Earth was in its early formation stage, characterized by intense volcanic activity, frequent impacts by asteroids and comets, and a very hot and inhospitable environment.	The Archean eon, which lasted from about 4 billion years ago to 2.5 billion years ago, saw the emergence of the first life forms on Earth. These early life forms were simple, single-celled organisms, such as bacteria and archaea, that lived in aquatic environments. These organisms played a crucial role in shaping the early Earth's atmosphere and laying the groundwork for the development of more complex life forms in the future.	During the Proterozoic eon, which lasted from about 2.5 billion years ago to 541 million years ago, the Earth experienced significant changes in its geology, climate, and the evolution of life. Oxygen levels in the atmosphere increased, leading to the development of oxygen-dependent life forms. Multicellular organisms, such as algae and simple animals, also appeared during this time.

Paleozoic Era (541 million years ago - 252 million years ago):

The Paleozoic Era is known as the **"Age of Invertebrates"** as it witnessed the emergence and diversification of various invertebrate groups.

- During this era, the oceans were the primary habitats, and life forms were largely limited to marine environments.
- The Age of Invertebrates saw the emergence of many major groups of invertebrates, including trilobites, brachiopods, mollusks, echinoderms, and arthropods.
- The Paleozoic era played a crucial role in shaping the early evolutionary history of life on Earth and laid the foundation for the rich biodiversity of invertebrates that we see today.

Periods under Paleozoic Era

The Paleozoic Era is divided into periods like: the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian periods. Each period was marked by significant events in the evolution and diversification of invertebrate life forms.

- The **Cambrian Period**, known as the "**Cambrian Explosion**," witnessed a rapid diversification of life forms, including the appearance of many new types of invertebrates with hard shells, such as trilobites and brachiopods.
- The **Ordovician and Silurian periods** saw the emergence of early fish and the colonization of land by plants and arthropods.
- The **Devonian Period** is often referred to as the **"Age of Fishes"** due to the diversification of fish species.
- The **Carboniferous Period** saw the emergence of the first amphibians and the formation of extensive coal deposits.
- The **Permian Period** saw the rise of reptiles and the evolution of many new types of marine invertebrates.

The end of the Paleozoic Era marked a significant transition in the history of life on Earth, leading to the rise of new groups of organisms in the subsequent Mesozoic Era, including the dominance of dinosaurs and the eventual emergence of mammals.

Mesozoic Era (252 million years ago - 66 million years ago):

The Mesozoic Era is often referred to as the **"Age of Reptiles."** It is a geological era characterized by the dominance and diversification of reptiles on Earth. During the Age of Reptiles, the dinosaurs, were the dominant land-dwelling animals.

Dinosaurs evolved into a wide range of forms, including small, fast-running predators, massive herbivores, and flying reptiles known as pterosaurs.

Periods Under the Mesozoic Era:

The Mesozoic Era is divided into three periods: the Triassic, Jurassic, and Cretaceous periods, each marked by significant events in the evolution and diversification of reptiles.

- The **Triassic Period** saw the emergence of the first dinosaurs, as well as other reptile groups such as the crocodiles, turtles, and early mammals.
- The **Jurassic Period** witnessed the rise of iconic dinosaurs such as the giant long-necked sauropods like Brachiosaurus and Diplodocus, as well as the early birds and the first true mammals.
- The **Cretaceous Period** saw the diversification of dinosaurs into various groups, including the famous Tyrannosaurus rex, Triceratops, and Velociraptors, as well as the appearance of advanced birds and early flowering plants.

Cenozoic Era (66 million years ago - present):

The Cenozoic Era is often referred to as the "Age of Mammals" as it saw the rise of mammals to prominence.

- After the mass extinction event that wiped out the dinosaurs around 66 million years ago, mammals diversified and occupied various ecological niches.
- Primates, including early humans, appeared during the Cenozoic Era, and the biosphere saw the evolution of modern mammals, birds, and flowering plants, which are dominant forms of life on Earth today.
- The Age of Mammals also saw significant climate changes and shifts in global ecosystems, which influenced the evolution and distribution of mammal species.
- Several major ice ages occurred, shaping the distribution of mammal populations and driving evolutionary adaptations.

Periods under the Cenozoic Era

The Cenozoic Era is divided into three periods: the Paleogene, Neogene, and Quaternary periods, each marked by significant events in the evolution and diversification of mammals.

- The **Paleogene Period** saw the diversification of early mammals, including the emergence of modern mammal groups such as primates, and rodents.

- The **Neogene Period** gave rise to the savannah and other grasslands. Prehistoric camels and horses evolved. Rhinoceroses, deer, and pigs also emerged.

- The **Quaternary Period**, which includes the last 2.6 million years, is characterized by the appearance of modern humans (Homo sapiens) and the development of complex societies and cultures.

Evolution of Man

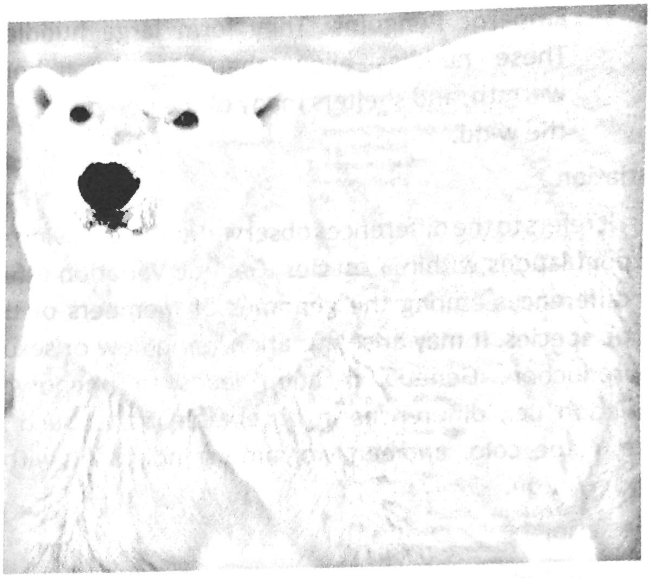
- **Dryopithecus and Ramapithecus**: They were primates that lived about 15 million years ago. Ramapithecus had more human-like features, while Dryopithecus was more ape-like. These early primates were not direct ancestors of humans, but they represent a stage in primate evolution that eventually led to the emergence of human-like beings.
- **Australopithecines:** About 3-4 million years ago, hominids with upright walking capabilities lived in eastern Africa. They are considered to be the earliest known human-like beings.
- **Homo Habilis**: They are considered the first human-like beings in the Homo genus. meaning "handyman," Homo Habilis emerged around 2 million years ago.
- **Homo Erectus:** Meaning «upright man,» appeared around 1.9 million years ago and is considered a more advanced stage in human evolution.
- **Neanderthals**: They lived in Europe and Asia between 400,000 and 40,000 years ago.
- **Homo sapiens:** They emerged in Africa around 300,000 years ago. Homo sapiens migrated out of Africa and eventually replaced other hominin species, including Neanderthals, as the dominant human species on Earth.
- **Modern Humans**: Homo sapiens continued to evolve and develop complex societies, cultures, and technologies.

Principles of Ecology

Adaptation

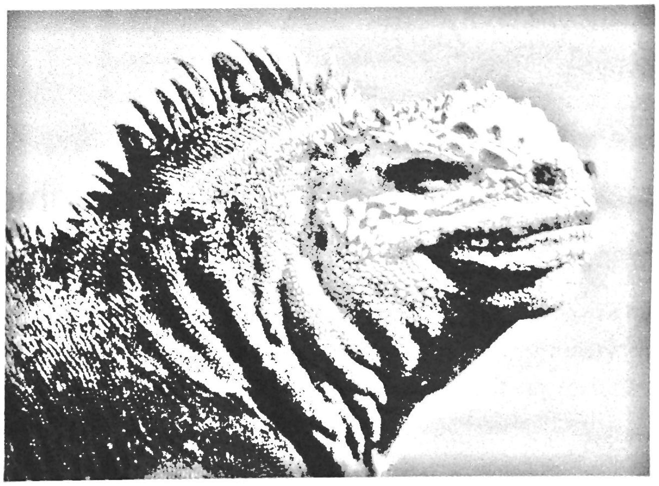
It is the process by which organisms survive and better adjust to their environment through morphological or structural changes, physiological processes, or behavioral mechanisms. Adaptations can be of different types viz. Morphological, Physiological and Behavioral.

- **Morphological Adaptation**: It involves changes in an organism's physical structure or anatomy. Examples of morphological adaptations include:
    - **Giraffe:** It has a long neck, which allows it to reach high branches and leaves for food. Additionally, the giraffe has a prehensile tongue which helps it to grasp and pull leaves from trees.
    - **Polar Bear:** It has thick fur that helps to keep it warm in the extremely cold temperatures. Further, it has large, wide paws and sharp claws that allow it to grip and climb on ice.



Polar Bear

- **Physiological Adaptation:** It involves changes in an organism's internal systems or processes. Example of Physiological Adaptations include
    - **Kangaroos**: In times of scarce food resources, kangaroos have the ability to tap into their internal fat stores through a process called internal fat oxidation. They use enzymes called lipases to break down the stored fat into usable energy.
    - **Marine Iguanas:** Marine iguanas have developed specialized glands that excrete excess salt from their bodies.



Marine Iguana

- **Behavioral Adaptation**: It includes changes in an organism's behavior or actions.
    - **Migration**: Birds migrate to escape cold, harsh climatic conditions. In the winter season, several birds migrate to India for food, breeding and nesting.

- **Emperor Penguins**: They form large huddles. These huddles allow them to share body warmth, and shelters many of the penguins from the wind.

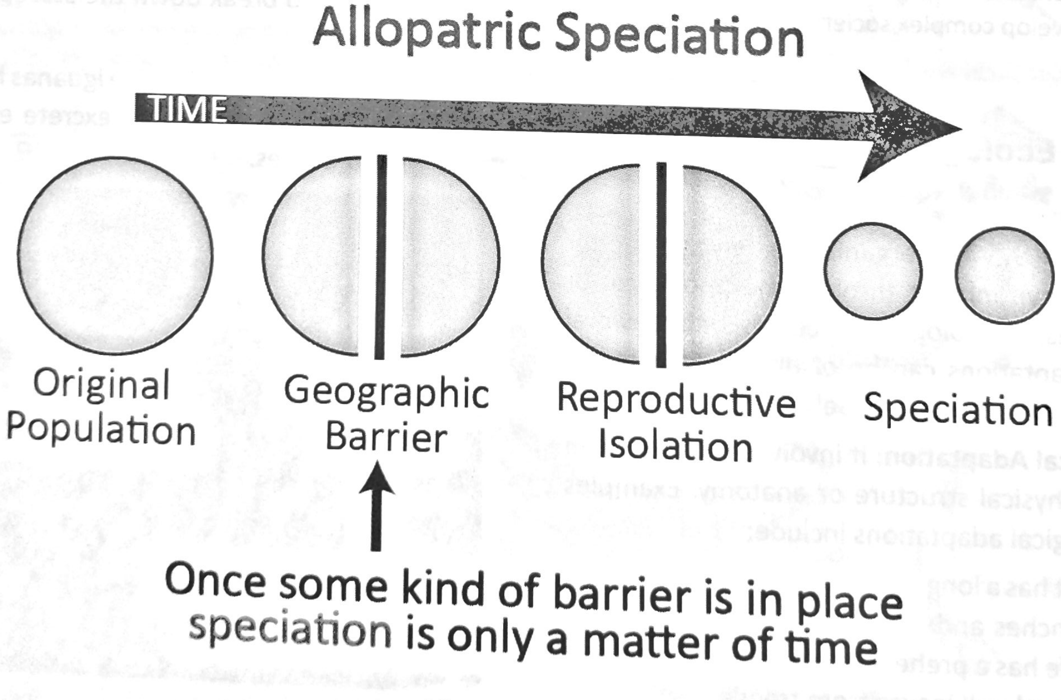
Variation

It refers to the differences observed among individuals or populations within a species. Genetic Variation refers to differences among the genomes of members of the same species. It may arise mutation, gene flow or sexual reproduction. Genetic variation leads to phenotypic variation i.e., differences in observable traits, such as size, shape, color, and behavior, among individuals within a population.

Speciation

It is the process by which new species arise from existing ones. This occurs when a population of organisms becomes genetically isolated from other populations of the same species and over time develops its own unique characteristics.

- **Allopatric speciation** occurs when a population becomes geographically isolated due to a physical barrier (such as mountains, ocean) from other populations of the same species. Eventually, the isolated population accumulates genetic and phenotypic differences that make it distinct from other populations. This leads to the formation of new species.
  - An example of allopatric speciation is the **Galápagos finch**. Different species of the finch live on different islands of the Galapagos Islands in the Pacific Ocean off the coast of South America. Because they are isolated, the birds don't breed with one another and have therefore developed into unique species with unique characteristics.
  - Another example of allopatric speciation is the case of the **Grand Canyon squirrels**. The Grand Canyon is a deep canyon that cuts through the Colorado Plateau. It is a major geographic barrier that has separated two populations of squirrels. The squirrels on the north rim of the canyon are called Abert squirrels. They are larger and have longer tails than the squirrels on the south rim of the canyon, which are called Kaibab squirrels. The two populations of squirrels are now considered to be separate species.



Allopatric Speciation

- **Artificial Speciation** is the creation of new species by scientists through lab experiments

Adaptive Radiation is the process through which a single ancestral species gives rise to many new species. These new species are adapted to different ecological niches.

Mutation

A change in the genetic material (DNA) of an organism is known as mutation. Mutations can occur spontaneously, as a result of errors in DNA replication. They can also be induced by exposure to mutagenic agents in the environment, such as radiation or chemicals.

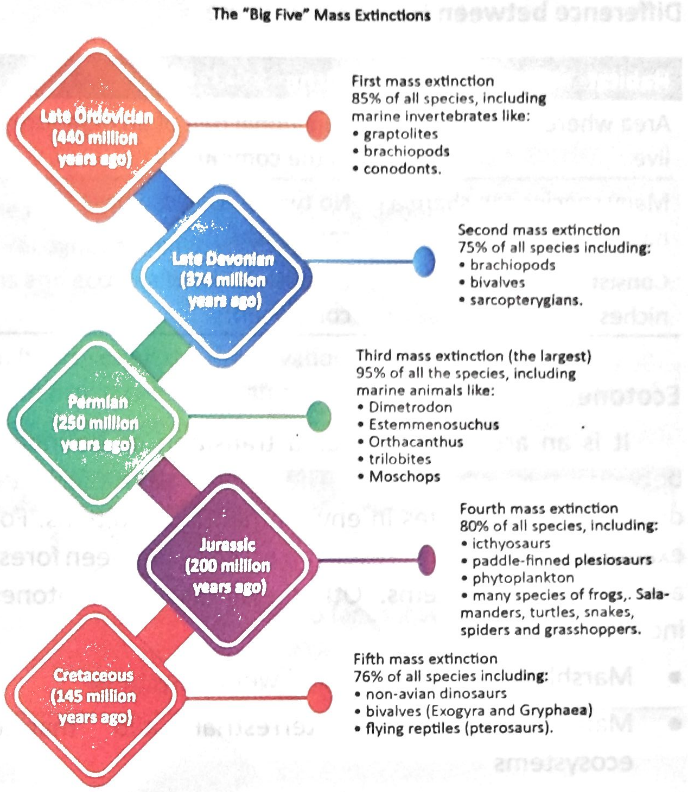
Natural Selection and Evolution

Evolution is the process of change in characteristics of populations of organisms over time. By evolution, species adapt in response to their changing environment. The theory of evolution was put forward by Charles Darwin and Alfred Russel Wallace in the 19th century. According to Darwin and Wallace, evolution occurs because of a phenomenon called natural selection.

- **Natural selection** is the process by which organisms that are better physically equipped to survive, grow to maturity, and reproduce. Natural selection is referred to "survival of the fittest". This is because the organisms most suited to their environment, reproduce most successfully, and are most likely to pass on their traits to the next generation.
- **Genetic drift**: It refers to the random fluctuations in the frequency of genetic traits in a population. For example, let's say there is a population of 100 rabbits. In this population, there are two gene variant (allele) for fur color: brown and black. The brown allele is more common, with 60 rabbits having the brown allele and 40 rabbits having the black allele. Now, let's assume that a natural disaster happens and half of the rabbits die. The new population will have only 50 rabbits. In this new population, the brown allele is still more common, but now it is present in 30 rabbits and the black allele is present in 20 rabbits. The frequency of the brown allele has decreased in the new population, simply because of chance.
- **Gene flow**: It is the transfer of genetic traits between different populations through migration and interbreeding. For example, Humans have been migrating around the world for thousands of years. This has led to the mixing of genes from different populations, which has helped to create the diverse human population that we see today.

Extinction

It is the complete disappearance of a species from Earth. Mass Extinction refers to a considerable increase in the degree of extinction when the Earth loses more than 3/4th of its species in a geologically short period of time. In 2022, many researchers have raised the concern that the earth is facing an ongoing sixth mass extinction -also known as Holocene Extinction and Anthropocene Extinction.


The "Big Five" Mass Extinctions
Late Ordovician (440 million years ago)
First mass extinction
85% of all species, including marine invertebrates like:
• graptolites
• brachiopods
• conodonts.
Late Devonian (374 million years ago)
Second mass extinction
75% of all species including:
• brachiopods
• bivalves
• sarcopterygians.
Permian (250 million years ago)
Third mass extinction (the largest)
95% of all the species, including marine animals like:
• Dimetrodon
• Estemmenosuchus
• Orthacanthus
• trilobites
• Moschops
Jurassic (200 million years ago)
Fourth mass extinction
80% of all species, including:
• icthyosaurs
• paddle-finned plesiosaurs
• phytoplankton
• many species of frogs,. Salamanders, turtles, snakes, spiders and grasshoppers.
Cretaceous (145 million years ago)
Fifth mass extinction
76% of all species including:
• non-avian dinosaurs
• bivalves (Exogyra and Gryphaea)
• flying reptiles (pterosaurs).

The 'Big Five' Mass Extinctions

Key Concepts in Ecology

Habitat

A habitat is an area or natural environment where an organism or group of organisms live. In simplest terms, it is the "home" of an organism. There are four major components of a habitat- **shelter, water, food and space.**

- **Microhabitat:** It is a smaller habitat within a larger one. For example, a fallen log inside a forest can provide microhabitat for insects that are otherwise not found in the wider forest.

Ecological Niche

The concept of niche was developed in 1917 by Joseph Grinnell, an American ecologist. The term niche denotes the role of an organism in the community. It includes what it eats, where it lives, where it reproduces and its relationship with other species.

Components of an Ecological Niche

- **Habitat Niche:** The area where a species live
- **Food Niche:** What it eats and which species it competes with.
- **Geo-ecological Niche:** Soil, Topography etc.
- **Reproductive Niche:** How and when it reproduces
- **Physical and chemical niche:** Factors like temperature and moisture.

Difference between Habitat and Niche

Habitat	Niche
Area where organism(s) live	Functional role of an organism in the community
Many species can share a habitat	No two species can have the same niche
Consist of numerous niches	Do not consist of such components

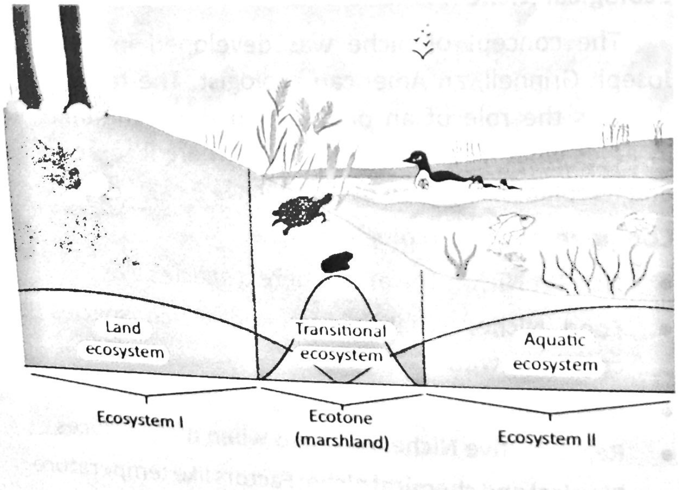
Ecotone

It is an area that acts as a transition or boundary between two ecosystems. The ecotones are created due to abrupt changes in environmental conditions. For example, grasslands represent an ecotone between forest and desert ecosystems. Other examples of ecotones include:

- Marshland between dry and wet ecosystems
- Mangroves between terrestrial and marine ecosystems
- Estuaries between saltwater and freshwater ecosystems.

Characteristics of Ecotone

- **Variation in Size:** An ecotone can be a broad belt; for example, between a forest and desert. It can be a narrow zone, for example, between a forest and a grassland.
- **Zone of Tension:** Ecotones possess conditions intermediate to the bordering ecosystems.
- **High Species Diversity:** In general, ecotones have a higher density of organisms and a greater number of species than adjacent ecosystems. Ecotones could also possess organisms that are entirely different from bordering ecosystems.



Ecotone

- **Edge Effect:** It refers to the changes in a population or community structure along the boundary of two habitats. There are species from both habitats, plus other species that are only found here. The species primarily found in the ecotones are called edge species.
- **Natural or Human-induced:** Apart from natural, ecotones could be manmade. For example, an ecotone between an agricultural field and a forest.

Significance of Ecotone

- **High Biodiversity**: Ecotones host great variety of organisms and are high biodiversity regions. This makes them highly sensitive zones.
- **Enable gene flow:** Ecotones often act as a bridge or vehicle for gene flow from one population to another, thus enabling greater genetic diversity.
- **Acts as a buffer**: They often act as buffer zones, protecting adjacent ecosystems. For example, wetlands absorb harmful pollutants and prevent them from seeping into river systems.
- **Conservation and restoration**: Ecotones are an active interest area for conservationists. The Ramsar Convention (1972) had recognized "If we can conserve and restore ecotones, we are effectively conserving a greater amount of biodiversity in nature."

Ecocline

It is the zone of gradual but continuous change between two ecosystems. There is no sharp boundary between two ecosystems in terms of species composition. It is based on the variation of abiotic factors across ecosystems such as temperature, salinity, humidity etc.

- **Example:** The transition between different vegetation zones on a mountain. As one climbs a mountain, the temperature and precipitation change. This causes a change in the types of plants that can grow in each zone.

Ecological Stress

It is defined as disturbance in ecological balance or ecosystem equilibrium. The disturbance can be physical, chemical, and biological.

Environmental Stressors:

- Physical stress–Examples- volcanic eruptions, windstorms, and explosions.
- Wildfire
- Pollution
- Thermal Stress

- Radiation Stress
- Climatic Stress
- Biological Stress

Deep and Shallow Ecology

Deep ecology is a radical approach to environmentalism. It emphasizes the intrinsic value of nature independent of human use. It seeks to shift the paradigm from anthropo-centric to one that recognizes the inherent value of all living organisms. Deep ecology advocates for the protection and preservation of all life forms and ecosystems, and not only those that are of benefit to humans.

Shallow Ecology is more anthropo-centric view of environmentalism. It focuses on the preservation and protection of the natural world for the benefit of humans. It is mainly concerned with the management of natural resources and the mitigation of pollution and other environmental problems in order to maintain a healthy environment for human life.

Deep Ecologism	Shallow Ecologism
Advocates radical change in human's relationship with nature.	Advocates continuing present lifestyle which specific changes to minimize environmental effects.
Believes in equal right to live and flourish. Nature has intrinsic value.	Nature is valuable so far as it serves human needs.
Rejects anthropocentricism	Rejects ecocentrism and biocentrism.

CHAPTER

2

ECOSYSTEMS-COMPONENTS & FUNCTIONS

ECOSYSTEM

The term "ecosystem" is an abbreviation for **"ecological system".** It is the **structural and functional unit of the environment** in which living organisms interact with one another and also the surrounding physical environment. The term ecosystem was first used by **Sir Arthur George Tansley** in 1935 to refer to a whole community of organisms and its environment as one unit.

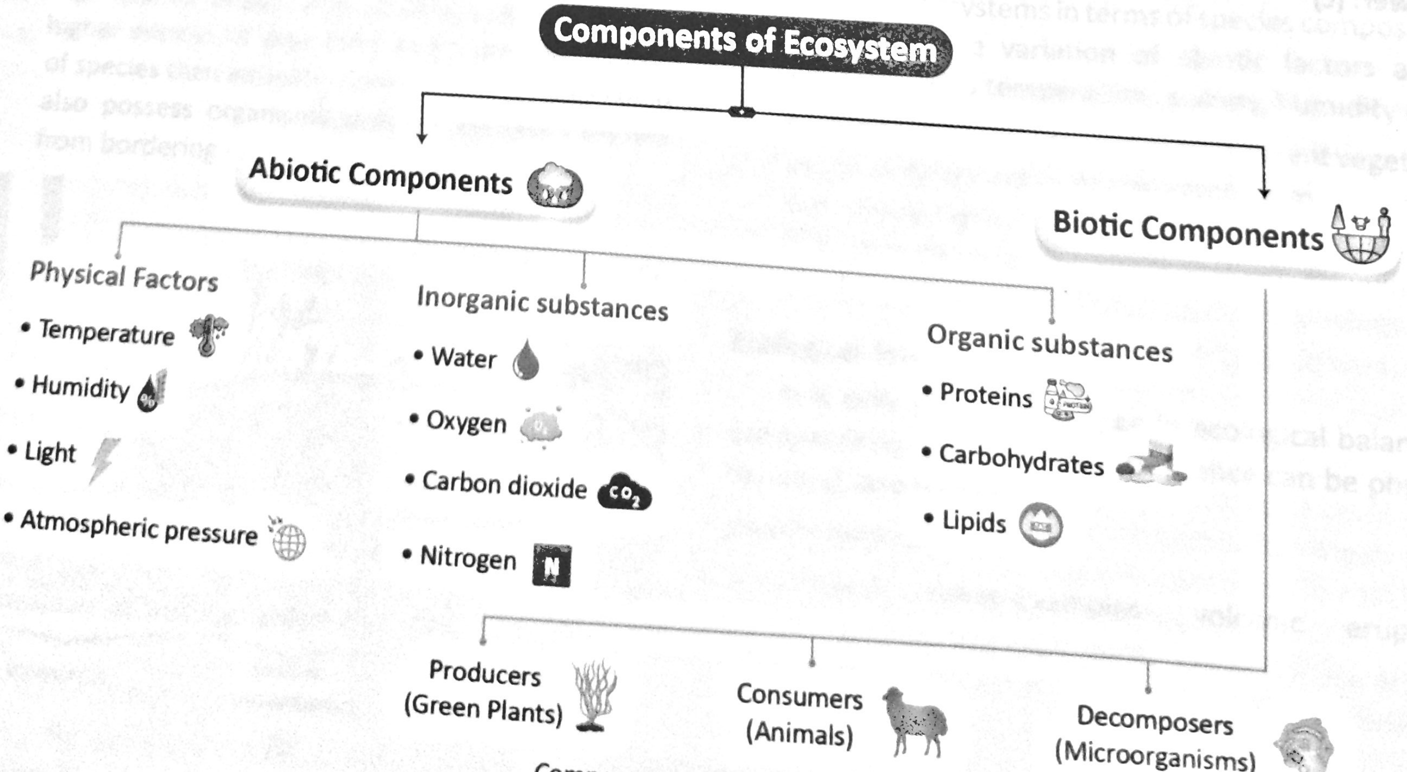
Characteristics of Ecosystem

The major characteristics of an ecosystem are as follows:

- **High Species Diversity:** There is a wide range of species (including plants, animals, fungi, and bacteria) present in an ecosystem. The diversity ensures the balance of the ecosystem and its long-term survival.
- **Interdependence:** Each organism plays a unique role in the ecosystem and all living organisms are interdependent on one another and on abiotic factors for their survival.
- **Energy Flow:** The sun is the primary source of energy in an ecosystem. This energy is then passed along the food chain from autotrophs (green plants) to herbivores to carnivores.
- **Nutrient Cycling:** There is cycling of nutrients such as carbon, nitrogen, and phosphorus between living and non-living components in an ecosystem. This process is crucial for the growth and survival of plants and other organisms in the ecosystem.
- **Succession:** Ecosystems are constantly changing over time, with new species colonizing areas that were previously uninhabited, and others dying out or being replaced by new species.

Components of Ecosystem

An ecosystem has two basic components viz. Abiotic Components and Biotic Components. Both abiotic and biotic components work together to create a functioning ecosystem.



Abiotic Components

These are the non-living components. They can be grouped into following three categories:

- **Physical factors:** It includes sunlight, temperature, rainfall, humidity and pressure. They sustain and limit the growth of organisms in an ecosystem.
- **Inorganic substances**: It includes Carbon dioxide, nitrogen, Sulphur, water, rock, soil, oxygen, phosphorus and other minerals.
- **Organic compounds**: It includes Carbohydrates, proteins, lipids and humic substances. They are the building blocks of living systems and therefore, acts as a link between the biotic and abiotic components.

Carrying Capacity and Limiting Factors

Carrying capacity refers to the maximum number of individuals of a particular species that an ecosystem can support over a sustained period of time. It is determined by a number of factors such as availability of resources such as food, water, environmental factors such as climate etc. These factors are known as the **limiting factors** and they restrict the growth, abundance, or distribution of a particular species within an ecosystem.

In an ecosystem, the population of a species will increase until reaches the carrying capacity. Then the population size remains relatively the same. If the population increases beyond the carrying capacity, resources with start depleting and the ecosystem will become unsuitable for the species to survive in.

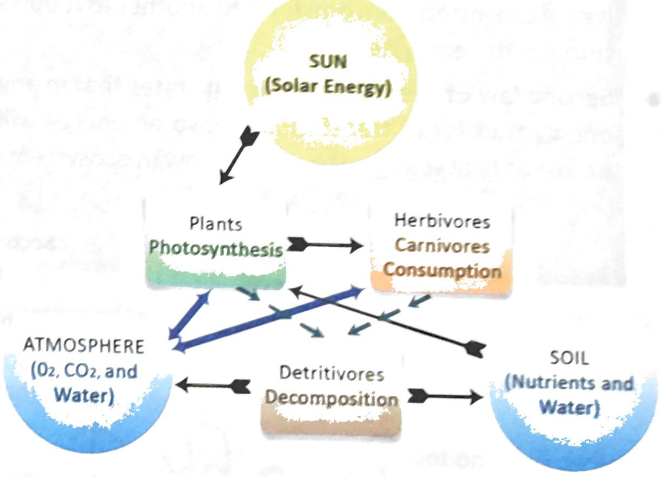
Let us understand the concept with an **example.**

In a forest ecosystem, the carrying capacity for a population of deer might be determined by the availability of food, such as grasses and shrubs. If the population of deer increases beyond the carrying capacity, food resources will deplete and will lead to starvation and a decline in the deer population. In this case, food availability is a limiting factor that restricts the growth of the deer population.

Biotic Components

These are the living components which include plants, animals, and microorganisms. They can be grouped into the following three major groups:

- **Producers (Autotrophs):** The plants that are capable of photosynthesis are known as the **producers or autotrophs**. Producers also include microorganisms that are capable of chemosynthesis. For example; bacteria near ocean vents
    - In a terrestrial ecosystem, major producers are plants.
    - Producers in an aquatic ecosystem are various species like phytoplankton, algae and higher plants.
- **Consumers (Heterotrophs):** Living organisms that consume food synthesized by the autotrophs are called **Consumers or Heterotrophs.** They can be classified into three broad categories.
    - **Herbivores-** Living organisms that feed directly on plants are called Herbivores. For example, cow, deer and rabbit etc.
    - **Carnivores-** Animals which eat other animals are called carnivores. For example, lion, cat, dog etc.
    - **Omnivores-** Organisms feeding upon both plants and animals are called omnivores. For example, humans etc.
- **Decomposers (Saprotrophs):** These are bacteria, fungi and invertebrates such as earthworms and millipedes that feed on dead decomposed and the dead organic matter of plants and animals.
    - They recycle the nutrients back into the soil, making them available for other organisms to use. They are also called **detrivores or detritus feeders.**



Relationship within an Ecosystem

Functions of Ecosystem

The ecosystem is a complex dynamic system. The interactions between biotic and abiotic components in an ecosystem result in different functions that are essential for the survival and well-being of the ecosystem as a whole. The functions of an ecosystem can be categorized into the following:

- Energy Flow
- Nutrient cycling (biogeochemical cycles)
- Ecological succession or ecosystem development
- Homeostasis (or cybernetic) or feedback control mechanisms.

The ecosystem self-regulates itself through two processes viz. Ecological succession and homeostasis. The interactions between abiotic and biotic components play the most determining role in these two eco-regulation processes.

Energy Flow

The flow or movement of energy through a series of organisms in an ecosystem is called **energy flow.** It is unidirectional which means it always flows from the producers to the higher level not vice-versa.It is a critical process as it allows transfer of energy from one organism to another.

Energy flow in an ecosystem is governed by the laws of thermodynamics, which describe the fundamental principles of energy transfer and transformation. Two laws of thermodynamics are relevant in understanding energy flow in an ecosystem.

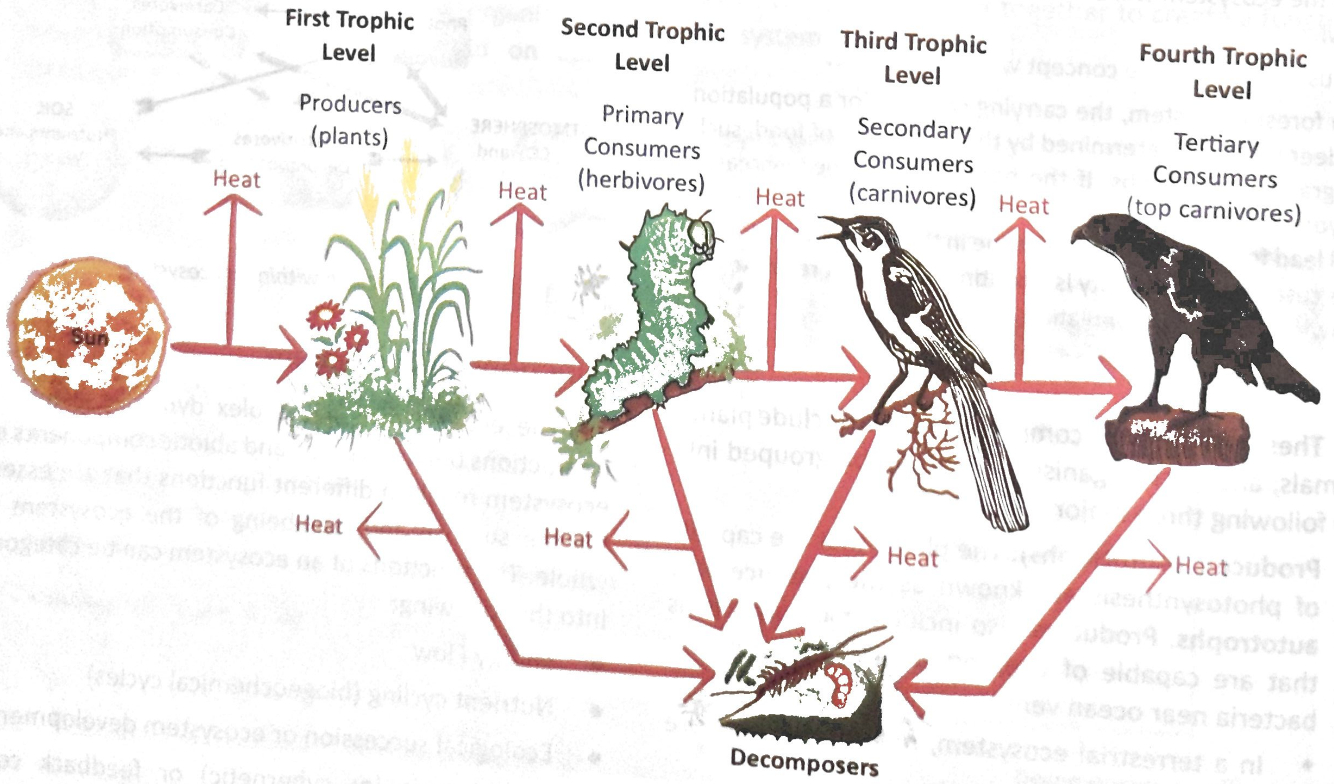
- **First law of thermodynamics:** It states that energy cannot be created or destroyed, only transformed from one form to another. The total amount of energy in an ecosystem remains constant. However, it gets converted from one form to another as it flows through the ecosystem.
- **Second law of thermodynamics**: It states that in any energy transfer or transformation, some energy will be lost as heat energy. The energy flow in ecosystems is not 100% efficient. When energy gets transferred from one organism to another, some of the energy is lost as heat energy during metabolic processes.

Trophic Level Interaction

Each nutrition level in the energy flow is known as the Trophic level. The word "Trophic" is derived from the word "Trophe" which means nourishment. The trophic level interactions are feeding relationships between different organisms in an ecosystem. In an ecosystem, organisms are placed at different trophic levels based on their feeding habits and the role they play in energy transfer.

Important Facts:

- Organisms at each trophic level depend on those at the lower trophic level for their energy demands.
- The amount of energy **decreases** at successive trophic levels.
- When any organism dies, it is converted to detritus or dead biomass that serves as an energy source for decomposers.
- **Standing Crop:** Each trophic level has a certain mass of living material at a particular time called as the standing crop. It is measured as the mass of living organisms (biomass) or the number in a unit area. The biomass of a species is expressed in terms of fresh or dry weight.



Trophic Levels

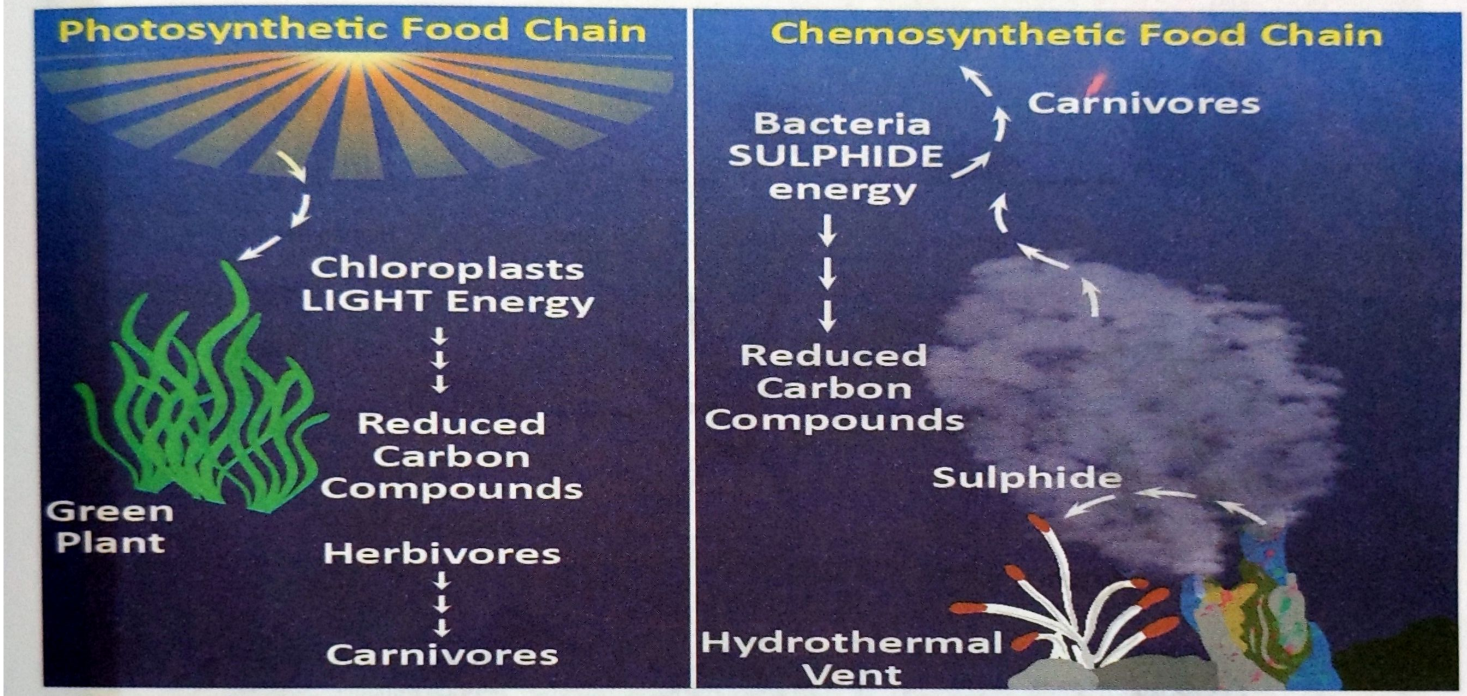
The trophic level interaction can be studied through food chains, food webs and ecological pyramids.

Food Chain

A food chain denotes the sequence of transfers of matter and energy in the form of food from organism to organism. It basically describes who eats whom in the wild. Sun is the only source of energy for all ecosystems on Earth except for the deep-sea hydro-thermal ecosystem. There is lack of sunlight penetration in the deep-sea hydrothermal ecosystem. Hence, the organisms residing there rely on chemical deposits and hydrothermal fluids as their source of energy.

DO YOU KNOW?

Photosynthetically active radiation (PAR): It refers to the spectral range of solar radiation that photosynthetic organisms can use for photosynthesis. This typically ranges from 400 to 700 nanometers (nm). Of the incident solar radiation less than 50 per cent of it is PAR. Plants capture only 2-10 per cent of the PAR and this small amount of energy sustains the entire living world.



Photosynthetic and Chemosynthetic Food Chain

Types of food chain

On the basis of source of energy, there are two major types of food chain: grazing food chain and detritus food chain.

Grazing Food Chain

The grazing food chain is found both in terrestrial and aquatic ecosystems. The food chain starts from the living green plants goes to grazing herbivores, and on to carnivores.

In aquatic ecosystems, the Phytoplankton acts as the primary producers which are eaten by the zooplankton, which is further eaten by fish, and so on.

Detritus Food Chain

The detritus food chain is dependent on dead organic matter. Decomposers such as bacteria and fungi break down the dead matter and release nutrients back into the ecosystem.

Difference between Grazing and Detritus Food Chain

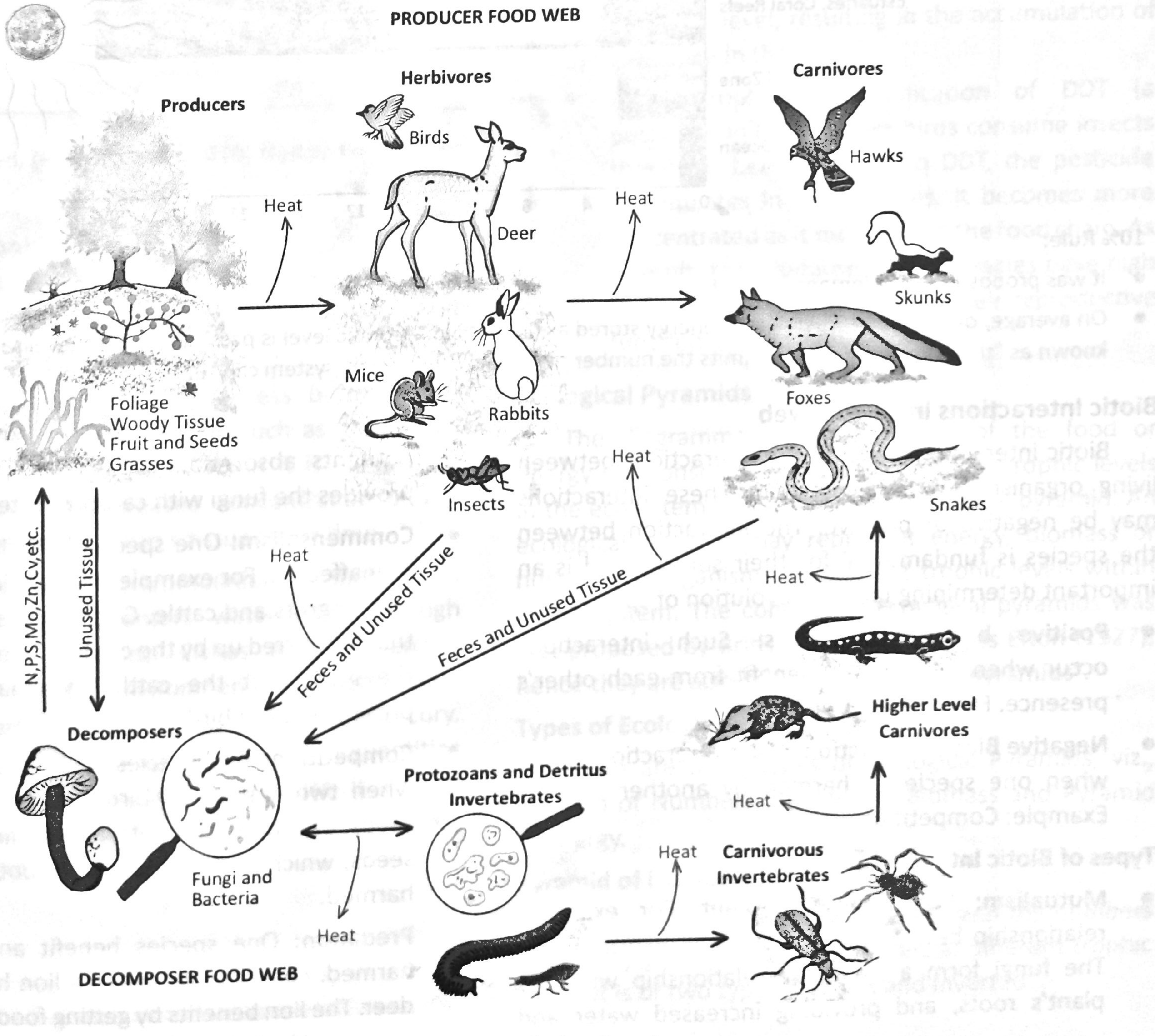
Grazing Food Chain	Detritus Food Chain
Energy for the food chain comes from solar energy	The source of energy is dead organic matter
The first trophic level is occupied by green plants	The first trophic level is occupied by decomposers such as bacteria and fungi
Generally, have large number of trophic levels	Number of trophic levels is low

Food Web

Ecosystem is a very complex structure that consists of a number of food chains. These food chains do not exist in isolation but interact with each other and often depend on each other. One animal may be a member of several different food chains. A food web shows the complex and interconnected network of a number of food chains in an ecosystem.

Difference between Food Chain and Food Web

Food Chain	Food Web
It depicts the linear flow of food energy	It shows the interconnecting food chains in an ecological community.
It is a single unit.	It consists of several food chains
It may consist of 4 - 6 trophic levels.	It consists of many numbers of trophic levels
It increases the instability of an ecosystem.	It increases the stability of an ecosystem
It does not improve the adaptability and competition amongst the organisms.	It improves the adaptability and competitiveness of organisms
The whole food chain can be disturbed if a disturbance occurs in a single trophic level.	The whole food web won't be disturbed if a disturbance occurs in a single trophic level.
Higher trophic level members can only feed upon a single type of organism in their lower trophic level	Higher trophic level members can feed upon several types of organisms in their lower trophic levels.



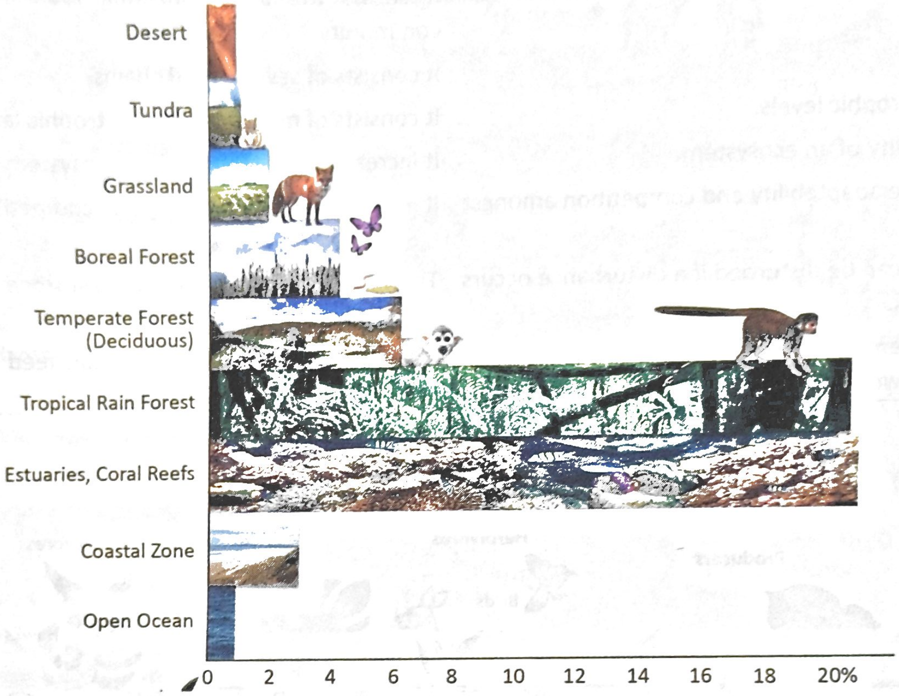
Two Types of Food Webs in a Forest

Concept of Ecological Efficiency

Ecological efficiency is the ratio between the amount of energy acquired from the lower trophic level and the amount of energy transferred from higher trophic level.

Basic Concepts:

- **Gross Primary Productivity**: All the biomass generated by primary producers is called gross primary productivity.
- **Net primary productivity**: It is what is left over after the primary producer has used the energy it needs for respiration. This is the portion that is available to be consumed by the primary consumers and passed up the food chain.



10% Rule:

- It was proposed by Lindemann in 1942.
- On average, only about 10 percent of energy stored as biomass in a trophic level is passed from one level to the next. This is known as "the 10 percent rule". It limits the number of trophic levels an ecosystem can support.

Biotic Interactions in a Food Web

Biotic interactions refer to the interactions between living organisms in an ecosystem. These interactions may be negative or positive. The interaction between the species is fundamental for their survival and is an important determining factor in evolution of species.

- ***Positive biotic interactions:*** *Such interactions occur when two species benefit from each other's presence. Example: Mutualism.*
- **Negative Biotic Interactions:** Such interactions occur when one species is harmed by another species. Example: Competition.

Types of Biotic Interactions

- **Mutualism:** Both species benefit. For example, relationship between plants and mycorrhizal fungi. The fungi form a symbiotic relationship with the plant's roots, and providing increased water and nutrients absorption capabilities, while the plant provides the fungi with carbohydrates.
- **Commensalism:** One species benefit and the other is unaffected. For example, the relationship between cattle egrets and cattle. Cattle egrets eat the insects that are stirred up by the cattle as they move through the grass, but the cattle are unaffected by the presence of the birds.
- **Competition:** Both species are harmed. For example, when two species of birds eat the same type of seeds. The birds compete for the limited supply of seeds, which can lead to one or both species being harmed.
- **Predation:** One species benefit and the other is harmed. For example, when a lion hunts and kills a deer. The lion benefits by getting food, while the deer is harmed by being killed.

- **Parasitism:** One species benefit and the other is harmed. For example, a tick attaching itself to a dog. The tick benefits by getting blood from the dog, while the dog is harmed by the tick's presence and potential transmission of diseases.
- **Amensalism:** One species is harmed, and the other is unaffected. For example, a plant releasing chemicals into the soil that inhibit the growth of other nearby plants. The releasing plant is unaffected, while the other plants are harmed.
- **Neutralism:** No net benefit or harm to either species. For example, two different species of birds having nests in the same tree.

Type	Species 1	Species 2
Mutualism	(+)	(+)
Commensalism	(+)	(0)
Amensalism	(–)	(0)
Competition	(–)	(–)
Predation	(+)	(–)
Parasitism	(+)	(–)
Neutralism	(0)	(0)

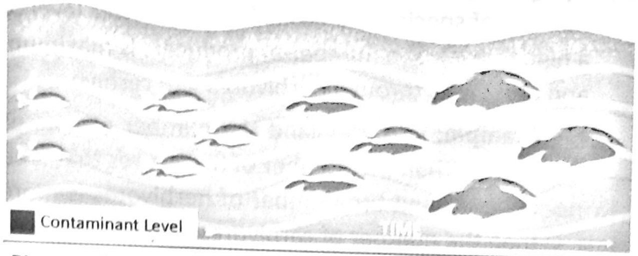
(+) Benefited, (–) Harmed, and (0) Neither benefited nor harmed.

Pollution at Trophic Levels

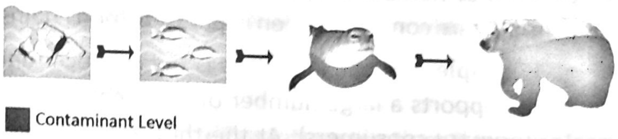
Pollutants and toxins build up in a food chain through the processes of bioaccumulation and biomagnification and cause threat to human health.

- **Bioaccumulation:** It is the process by which an organism absorbs a substance, such as a chemical or a toxin, at a rate greater than it is eliminated. This results in an increased concentration of the substance in the organism's tissues over time.
  - **For example**, bioaccumulation of mercury in fishes. Mercury enters waterbodies through industrial processes. Fishes absorb mercury directly from the environment and also by eating other organisms that have absorbed mercury. Over time, the fish accumulates large quantities of mercury in its tissues because it cannot eliminate the mercury from its body as quickly as it is absorbing it.

Bioaccumulation



Biomagnification



Bioaccumulation and Biomagnification

- **Biomagnification:** It is the process by which the concentration of a substance increases as it moves up the food chain. This occurs because each organism at a higher trophic level consumes many organisms at a lower trophic level, resulting in the accumulation of the substance in their tissues.
  - **For example**, biomagnification of DDT (a pesticide) in birds. When birds consume insects that have been exposed to DDT, the pesticide accumulates in their bodies. It becomes more concentrated as it moves up in the food chain. As a result, top predators such as eagles have high levels of DDT posing harm to their reproductive function and survival.

Ecological Pyramids

The diagrammatic representation of the food or energy relationship between the different trophic levels in the ecosystem is known as the ecological pyramid. An ecological pyramid may represent energy, biomass or numbers of organisms at different trophic levels within an ecosystem. The concept of Ecological pyramids was first proposed by British Ecologist, **Charles Elton** (1927), hence they are also known as **"Eltonian pyramids"**.

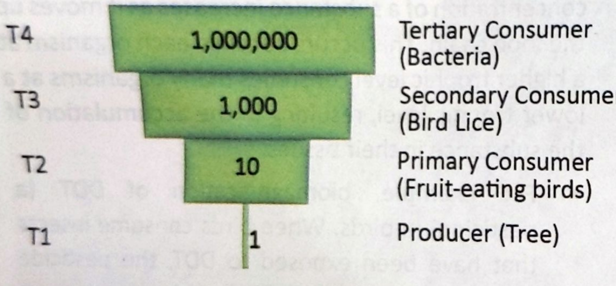
Types of Ecological Pyramids

There are three types of Ecological Pyramids, viz., Pyramid of Numbers, Pyramid of Biomass and Pyramid of Energy.

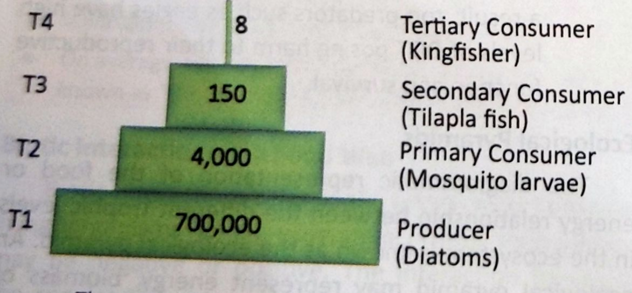
Pyramid of Numbers

It represents the relationship between the numbers of primary producers and consumers at different trophic levels. It is of two types- Upright and Inverted

- **Upright Pyramid of Number:** In this pyramid, the number of species decreases from the lower level to a higher level. The number of producers is maximum and decreases through herbivores and carnivores.
    - **Example:** In a grassland the number of grasses is more than the number of herbivores that feed on them and the number of herbivores is more than the number of carnivores.
- **Inverted Pyramid of Number:** In some instances, the pyramid of number may be inverted. Such inverted pyramids are commonly seen in parasitic food chains.
    - **Example**: A single large tree is the producer and it supports a large number of fruits eating birds (primary consumers). At the third trophic level, hundreds of bird lice parasitize each bird. The top trophic level is occupied by hyperparasites such as bacteria and fungi, which live on bird lice.


T4
1,000,000
Tertiary Consumer (Bacteria)
T3
1,000
Secondary Consumer (Bird Lice)
T2
10
Primary Consumer (Fruit-eating birds)
T1
1
Producer (Tree)

An inverted pyramid of numbers of a parasitic food chain

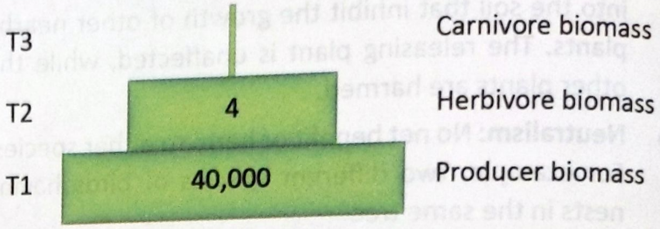

T4
8
Tertiary Consumer (Kingfisher)
T3
150
Secondary Consumer (Tilapla fish)
T2
4,000
Primary Consumer (Mosquito larvae)
T1
700,000
Producer (Diatoms)

The pyramid of numbers in an aquatic ecosystem

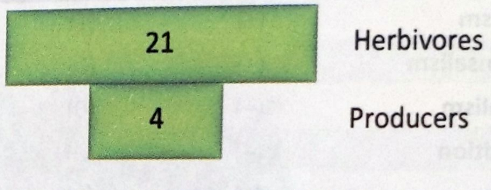
Pyramid of Biomass

It represents the total standing crop biomass at each trophic level. It is expressed as gm/unit area or kilo cal/ unit area. It is of two types: Upright and Inverted

- **Upright Pyramid of Biomass:** Here, the biomass of the producers is maximum and it decreases to the higher levels. Most of the ecosystem on earth represents the upward pyramid of biomass.
- **Inverted Pyramid of Biomass:** An inverted pyramid of biomass can be seen in certain aquatic ecosystems. For example,
    - **Example:** In an aquatic ecosystem, phytoplankton are the producers. They have they have very short life cycles and a rapid turnover rate (i.e., they are rapidly replaced by new plants). Consequently, the mass of the zooplanktons (herbivores) is greater than that of the producers. This results in an inverted pyramid of biomass.



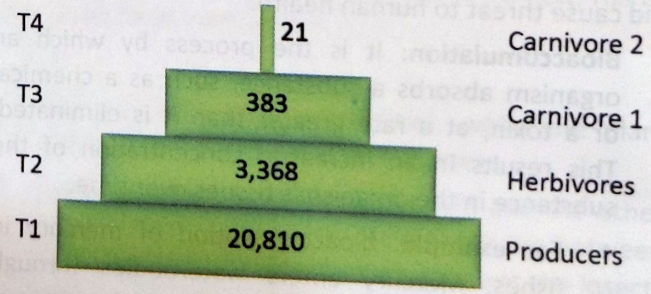
A typical pyramid of biomass from a tropical forests



An inverted pyramid of biomass from an aquatic system

Pyramid of Energy

It represents the total amount of energy at each trophic level. Energy is expressed in terms of rate such as kcal/unit area /unit time or Cal/unit area/unit time. Pyramid of **energy is always upright, can never be inverted**. This is because when energy flows from a particular trophic level to the next trophic level, some energy is always lost as heat at each step.

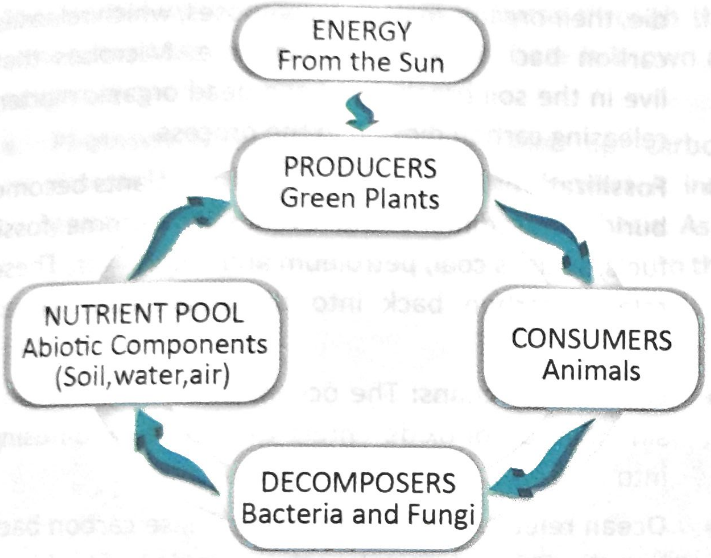


Pyramids of energy (Kcal m-2 y-1) for an aquatic system

Nutrient Cycling

Biogeochemical cycles or Nutrient Cycles are the pathways by which chemical elements and compounds move through the biotic and abiotic components of Earth's ecosystems. The constant interaction between the biotic and abiotic components of the biosphere makes it a dynamic, but stable system.

There are two components in any biogeochemical cycle, viz. reservoir and exchange pool. The **reservoir** is a large, slow moving storehouse of chemical elements and compounds. It is generally abiotic (example- the atmosphere or hydrosphere) but can also be biotic (example- biomass of a forest which acts a reservoir of elements like carbon).



Cyclic flow of nutrient materials through an ecosystem

The **exchange or cycling pool** is a smaller but more active portion. It is concerned with rapid exchange of chemical elements and compounds between the biotic and abiotic aspects of an ecosystem.

Types of Biogeochemical Cycles

Biogeochemical cycles can be classified into two types based on the type of reservoir- Gaseous and Sedimentary.

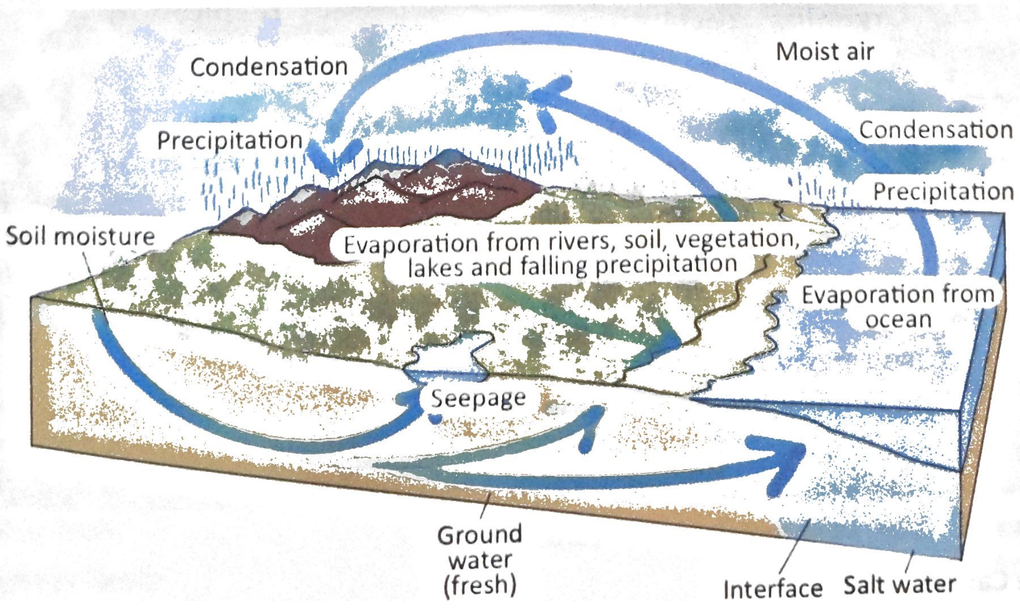
Gaseous Cycles

The atmosphere or hydrosphere act as the reservoir in case of gaseous cycles. The carbon, nitrogen, oxygen are important gaseous cycles

Hydrological (Water Cycle)

There is a constant and continuous circulation of water from the Earth's surface to the atmosphere and back to the Earth's surface. This circulation of water is called the **water cycle or the hydrological cycle.**

- **Evaporation:** The Sun's heat provides energy to evaporate water from the Earth's surface (oceans, lakes, etc.).
- **Transpiration and Evapotranspiration**: Plants also lose water to the air by the process called transpiration. The term evapotranspiration denotes the combined process of evaporation and transpiration.
- **Condensation:** The water vapor eventually condenses, forming tiny droplets in clouds.
- **Precipitation:** When the clouds meet cool air over land, precipitation (rain, sleet, or snow) occurs, and water returns to the land (or sea).
- **Groundwater**: Some of the precipitation soaks into the ground. Some underground water is trapped between rock or clay layers, called groundwater.
- **Runoff:** Most of the water flows downhill as runoff (above ground or underground), eventually returning to the seas.

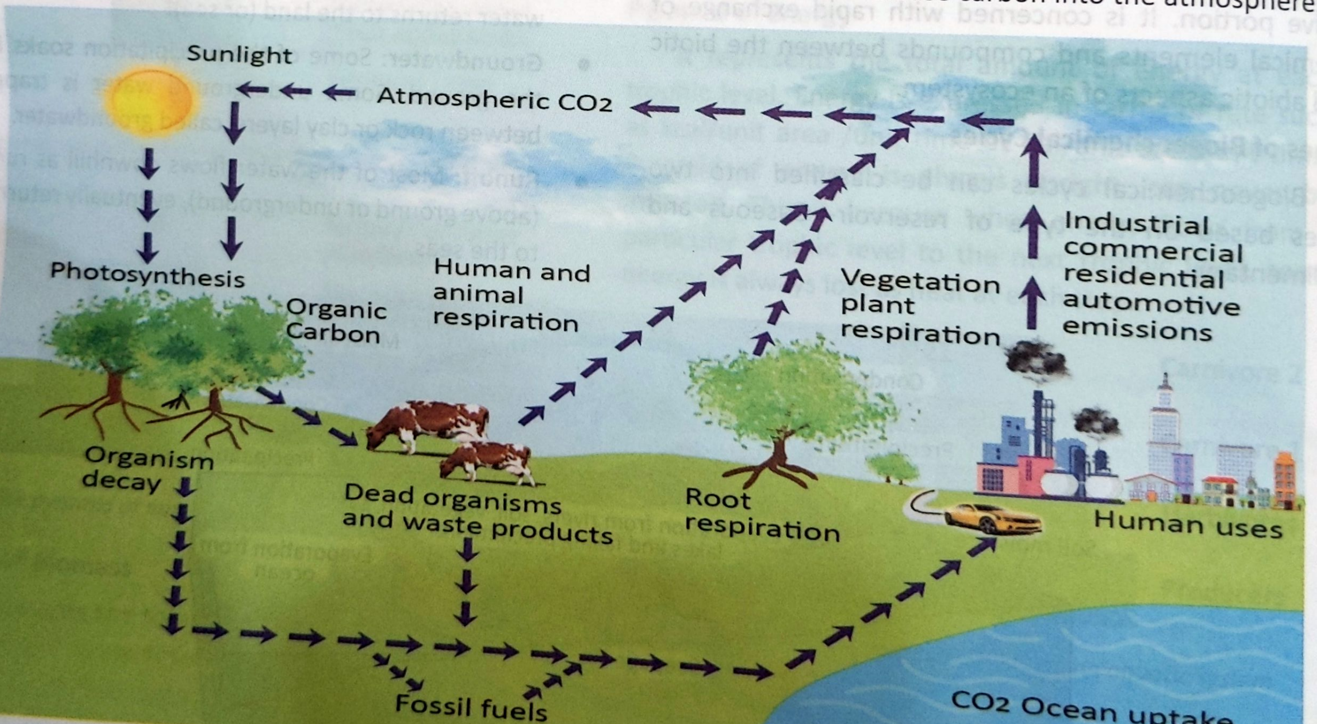


Carbon Cycle

Carbon is one of the elements of life. Carbon is a constituent of all organic compounds. Carbon compounds also regulate the Earth's temperature. It also provides energy which is crucial for running the global economy.

The carbon cycle describes the circulation of carbon in various forms between the Earth's biosphere, hydrosphere, atmosphere, and geosphere. Carbon is present in air as carbon dioxide (0.03%). It is present carbonates and bicarbonates or molecular CO2 (aq) in surface water and groundwater.

- **Carbon dioxide fixation:** The carbon cycle starts with algae and terrestrial green plants fixing carbon dioxide through the process of photosynthesis. By this process carbon dioxide and water are converted into simple carbohydrates.
- **Movement along the food chain:** Through the food chain, the carbon is then passed on to herbivores and carnivores which convert them into other forms.
- **Respiration:** Carbon dioxide is directly added to the atmosphere by animals and some other organisms as a by-product of respiration.
- **Decomposition:** Further, when plants and animals die, their organic matter decomposes, which releases carbon back into the atmosphere. Microbes that live in the soil break down the dead organic matter, releasing carbon dioxide in the process.
- **Fossilization:** Some dead animals and plants become buried in sediment and eventually become fossil fuels, such as coal, petroleum and natural gas. These release carbon back into the atmosphere when burned.
- **Uptake by Oceans:** The oceans are a major carbon sink. Carbon di oxide enters the ocean by diffusing into the sea surface waters and dissolving.
- **Ocean release:** The oceans also release carbon back into the atmosphere when the ocean's surface layers warm up.
- **Weathering:** Over time, rocks on the Earth's surface weather and release carbon into the atmosphere.


Sunlight
Atmospheric CO2
Photosynthesis
Organic Carbon
Human and animal respiration
Vegetation plant respiration
Industrial commercial residential automotive emissions
Organism decay
Dead organisms and waste products
Root respiration
Human uses
Fossil fuels
CO2 Ocean uptake

Carbon Cycle

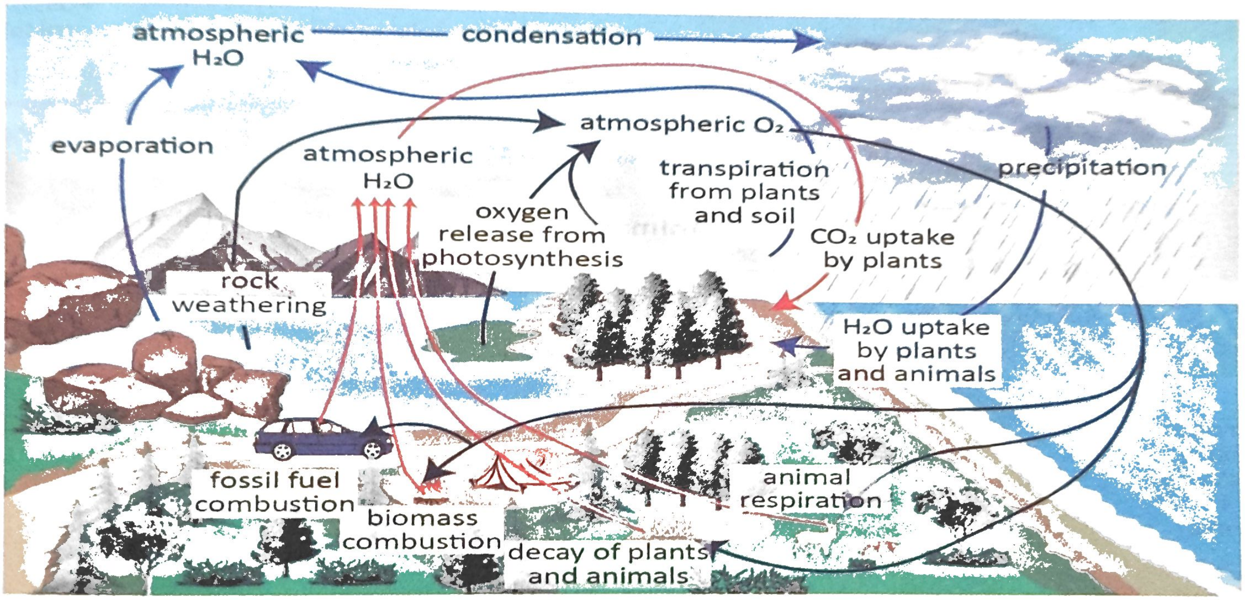
Human Impact on the Carbon Cycle

- **Burning of Fossil Fuels**: Combustion of fossil fuels releases excess carbon di oxide into the atmosphere.
- **Deforestation:** Forests sequester or store carbon mainly in trees and soil. Rampant deforestation leads to poor sequestration and thus releases carbon dioxide in the atmosphere.
- **Carbon dioxide in Oceans**: The ocean absorbs a lot of carbon dioxide that is released from burning fossil fuels. The extra CO2 is lowering the ocean's pH (ocean acidification).

Oxygen Cycle

Oxygen is a colorless, odorless, tasteless gas. It is essential for survival of living organisms on earth. Oxygen makes around 21% of the air in the atmosphere. The movement of oxygen in various forms through the atmosphere, biosphere and the lithosphere is known as **oxygen cycle.**

- **Photosynthesis:** Green plants take up carbon dioxide from the atmosphere and convert it into glucose through the process of photosynthesis. As a byproduct of this process, oxygen is released into the atmosphere.
- **Respiration:** During respiration, plants and animals use oxygen and release carbon dioxide (CO2) into the atmosphere.
- **Combustion:** Oxygen is required during combustion of fossil fuels, wood, plastics etc. During the process, carbon dioxide is released into the atmosphere. Inorganic substances and other minerals are also oxidized by oxygen
- **Decomposition:** During the process of decomposition, oxygen is consumed and carbon dioxide is released.
- **Absorption in Water Bodies:** Oxygen is absorbed by water bodies through diffusion at the air-water interface, and through the activities of photosynthetic organisms such as phytoplankton.



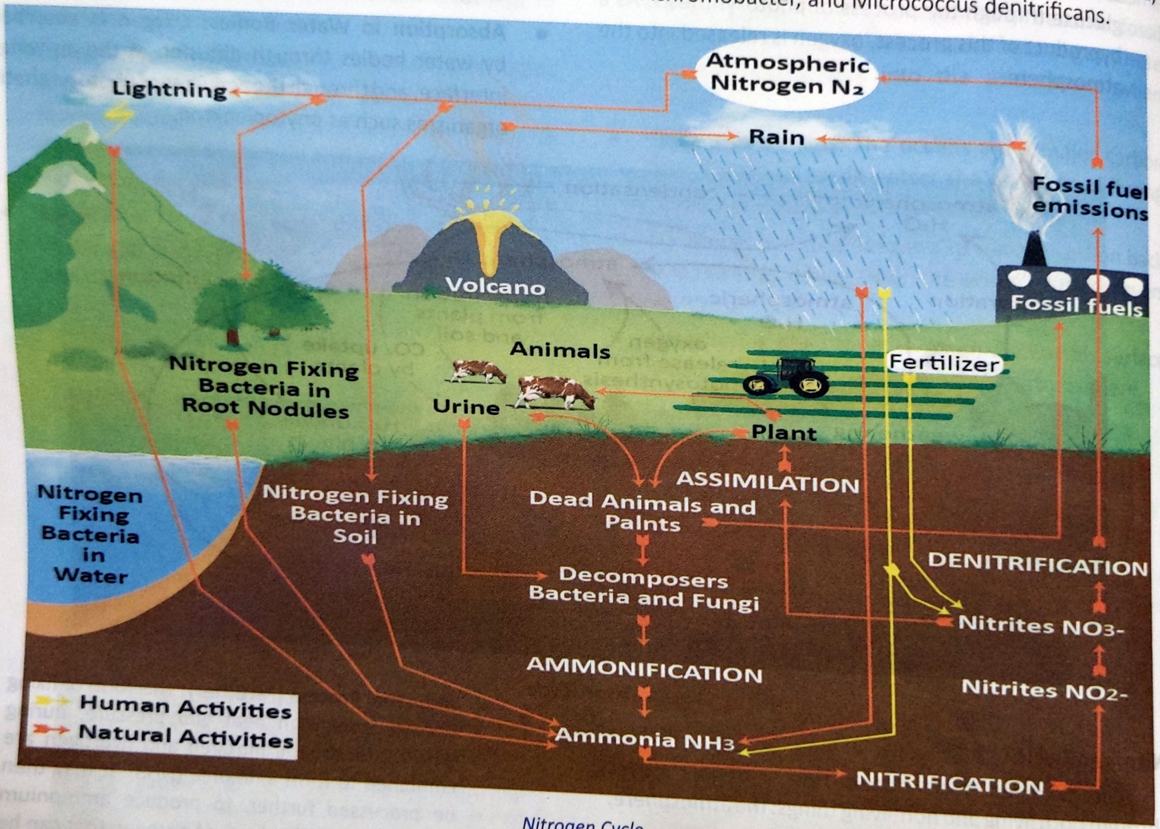
Oxygen Cycle

Nitrogen Cycle

The nitrogen cycle shows how nitrogen moves through both living and non-living things: the atmosphere, soil, water, plants, animals and bacteria.

- **Nitrogen Fixation:** The Earth's atmosphere contains a large amount of nitrogen gas (N2) but it cannot be used directly by plants without undergoing a transformation. By the process of nitrogen fixation, atmospheric nitrogen (N2) is converted into a biologically useful form.
  - **How nitrogen is fixed?**
    - **Lightning:** A small amount of nitrogen can be fixed when lightning provides the energy needed for N2 to react with oxygen, producing nitrogen oxide, NO, and nitrogen dioxide, NO2. These forms of nitrogen then enter soils through rain or snow.
    - **Industrial Process (Fertilizer):** This form of fixing occurs under high heat and pressure, during which atmospheric nitrogen and hydrogen are combined to form ammonia (NH3). It may then be processed further, to produce ammonium nitrate (NH4NO3). a form of nitrogen that can be added to soils and used by plants.
    - **Bacteria:** Nitrogen fixation occurs naturally in the soil by bacteria. **Examples:** Symbiotic: Rhizobium (associated with leguminous plants); Frankia (associated with actinorhizal plants) Azospirilum (associated with cereal grasses), Free-living: Anabaena, Nostoc, Azotobacter, Beijernicika, and Clostridium.
- **Nitrification:** It is a process by which ammonia is converted into nitrates or nitrite by Nitrosomonas and Nitrococcus bacteria respectively. Another type of soil bacteria called Nitrobacter can covert nitrate into nitrite.

- **Assimilation:** By the process of assimilation, the nitrogen fixed by plants is converted into organic molecules such as proteins, DNA, RNA etc. These molecules make the plant and animal tissue.
- **Ammonification:** Living organisms produce nitrogenous waste products such as urea and uric acid. By the process of ammonification, these waste products and the dead remains of organisms are converted back into inorganic ammonia by certain soil bacteria. Examples of ammonifying bacteria include bacillus, proteus, clostridium, pseudomonas and streptomyces.
- **Denitrification:** The process by which nitrates are converted back into gaseous nitrogen is called denitrification. Denitrification occurs because in deep layers of soil, oxygen is not available and the soil bacteria use these nitrogen compounds instead of oxygen. Examples of denitrifying bacteria include Pseudomonas, Thiobacillus denitrificans, Serratia, Achromobacter, and Micrococcus denitrificans.



Nitrogen Cycle

Key Facts about Nitrogen

- Nitrogen makes up 78% of the air, by volume.
- It is colorless, odorless and tasteless in gaseous form.
- Looks the same as water when in liquid form.

Significance of Nitrogen

- Important for plants and animals to survive
- Core component of amino acids, nucleic acids, DNA and RNA
- Basic building block of proteins

Human Impact on the Nitrogen Cycle

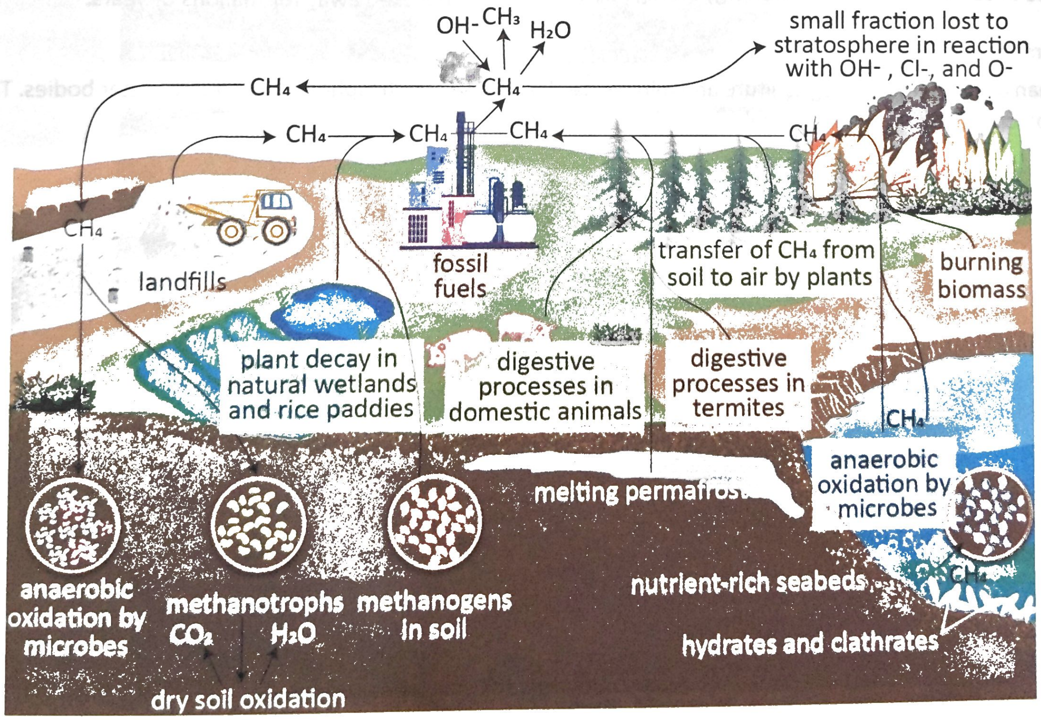
- **Excessive use of Fertilizers:** Fertilizers containing nitrogen compounds such as ammonia and nitrate are used to increase crop yield. Excessive use of fertilizers leads to excess of nitrogen in soil. Excess nitrogen can leach into waterways and cause eutrophication, leading to harmful algal blooms and dead zones.
- **Burning of fossil fuels:** It releases nitrogen oxides into the atmosphere. Nitrogen oxides contribute to air pollution and cause acid rain.

- **Livestock production**: It leads to release of excess nitrogen which eventually leach into waterways and contribute to eutrophication It also contributes to air pollution.
- **Industrial activities**: Production of nitrogen-based chemicals, can increase the amount of nitrogen in the environment.
- **Deforestation**: It impacts the nitrogen cycle by affecting the nitrogen fixation process. It can also lead to soil degradation and reduce the amount of available nitrogen for plant growth.

Methane Cycle

Methane is an odorless, colorless, tasteless gas that is lighter than air. It is the main component of natural gas. Methane is also one of the greenhouse gases.

- **Sources of methane:** The natural sources of methane include wetlands, gas hydrates, termites, oceans, freshwater bodies and other sources such as wildfires. The anthropogenic sources of methane include fossil fuel production, the livestock production, rice cultivation, biomass burning, and waste management.
- **Methanogenesis:** It occurs in anaerobic environments, such as wetlands, rice paddies, and the digestive tracts of ruminants. During the process, certain types of bacteria break down organic matter and produce methane as a byproduct.
- **Methane oxidation**: During this process, certain microorganism (methanotrophs) use methane as a source of energy and convert it into carbon dioxide and water.
- **Methane Sinks:** Atmosphere (the troposphere) is the largest sink of methane. Methane is removed from the atmosphere by reactions initiated by hydroxyl radical (HO). The reaction breaks down methane into carbon dioxide and water vapor. Methane can also be removed from the atmosphere by being absorbed into certain types of soils.


OH-
CH_3
H_2O
small fraction lost to stratosphere in reaction with OH- , Cl-, and O-
CH_4
CH_4
CH_4
CH_4
CH_4
CH_4
CH_4
landfills
fossil fuels
transfer of CH_4 from soil to air by plants
burning biomass
plant decay in natural wetlands and rice paddies
digestive processes in domestic animals
digestive processes in termites
CH_4
melting permafrost
anaerobic oxidation by microbes
anaerobic oxidation by microbes
methanotrophs
CO_2
H_2O
methanogens in soil
nutrient-rich seabeds
CH_4
hydrates and clathrates
dry soil oxidation

Methane Cycle

Methane Hydrates

Methane hydrates, also known as **methane clathrates** are solid compounds made up of water molecules that contain trapped methane gas.

- **Distribution**: They are found in large quantities in the shallow seafloor and in the Arctic permafrost regions.
- **Relationship with Climate Change:** If global temperatures continue to rise, there is a risk that the hydrates could melt and release large amounts of methane into the atmosphere. This process of melting and releasing methane from hydrates is known as hydrate destabilization. The release of methane into the atmosphere would further accelerate climate change.

Sedimentary Cycles

The earth's crust acts as the reservoir for sedimentary cycles. The Sulphur and phosphorous cycles are examples of sedimentary cycles.

Phosphorus Cycle

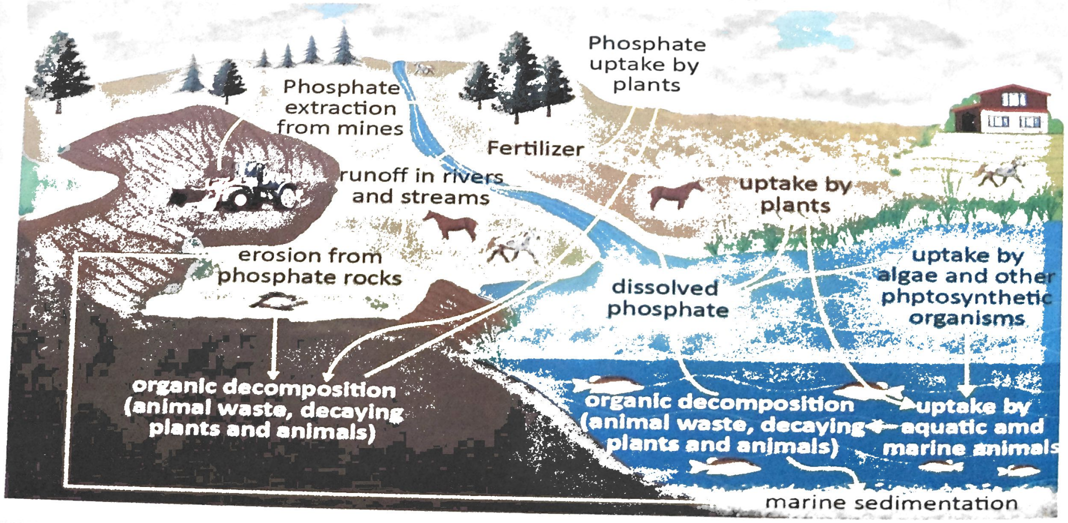
Phosphorus is an essential nutrient for animals and plants. It is a constituent of protoplasm and DNA. It plays a vital role in cell development and energy storage (ATP).

The phosphorus cycle describes the movement of phosphorus between the Earth's surface, soil, water bodies, and living organisms. It is important to note that Phosphorous is not present in the atmosphere. It therefore lacks the atmosphere component in the cycle making the cycle endogenic.

- **Weathering:** Phosphorus is present in rocks and minerals, and it is released into the soil through weathering, erosion, and volcanic activity.
- **Absorption:** Plants absorb phosphorus from the soil in the form of phosphate ions (PO43-), which are essential for building DNA, RNA, and ATP.
- **Consumption:** Animals obtain phosphorus by consuming plants or other animals.
- **Excretion:** When plants and animals die, phosphorus is returned to the soil through decomposition and excretion. Feces and urine contain large amounts of phosphorus, which can enrich the soil and support plant growth.
- **Sedimentation:** Over time, phosphorus can become buried in sediment and rock formations, where it can be locked away for millions of years.

Human Impact on Phosphorus Cycle

Human activities, such as agriculture and mining, can lead to excess phosphorus runoff into water bodies. This leads to eutrophication and algal blooms, which can harm aquatic ecosystems.


Phosphate uptake by plants
Phosphate extraction from mines
Fertilizer
runoff in rivers and streams
uptake by plants
erosion from phosphate rocks
dissolved phosphate
uptake by algae and other phptosynthetic organisms
organic decomposition (animal waste, decaying plants and animals)
organic decomposition (animal waste, decaying plants and animals)
uptake by aquatic amd marine animals
marine sedimentation

Phosphorus Cycle

Sulphur Cycle

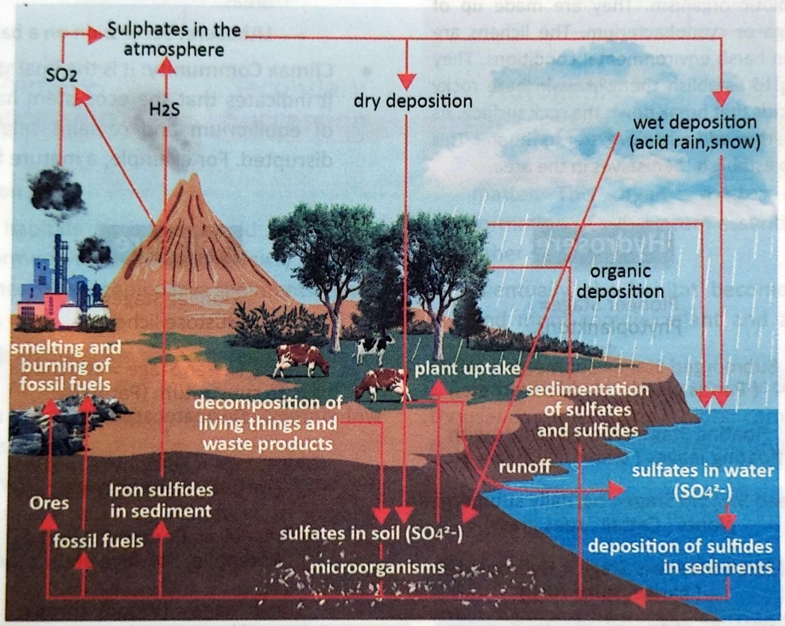
Sulphur is a yellow, odorless, nonmetallic element. It is an important constituent of protein and vitamin. It plays a significant role in protein and enzyme functioning in plants and animals.

It is found naturally in the lithosphere, atmosphere and hydrosphere. In the earth's crust, Sulphur occurs in the form of gypsum and pyrite. Oceans are the largest reservoir of Sulphur. Sulphur is present in the form of sulphates, hydrogen sulfide gas, and elemental Sulphur.

The Sulphur cycle depicts the movement of Sulphur between the lithosphere, atmosphere, water bodies and living organisms.

Movement in the biosphere:

- **Release of Sulphur:** The Sulphur is released into soil and water by weathering rocks.
- **Uptake by plants and animals**: Most of the organisms assimilate Sulphur in the organic form (sulphate ions). Only few organisms utilize organic Sulphur via amino acids. Plants assimilate sulphate and from them Sulphur enters into the animals via the food chain.
- **Decomposition**: Bacteria reduce Sulphur from the dead organic matter and it is then released into the atmosphere. Examples of Sulphur reducing organisms include Desulfovibrio, green and purple sulfur bacteria, chemolithotrophs etc.


Sulphates in the atmosphere
SO2
H2S
dry deposition
wet deposition (acid rain,snow)
organic deposition
smelting and burning of fossil fuels
plant uptake
decomposition of living things and waste products
sedimentation of sulfates and sulfides
runoff
sulfates in water (SO4²-)
Ores
Iron sulfides in sediment
fossil fuels
sulfates in soil (SO4²-)
microorganisms
deposition of sulfides in sediments

Sulphur Cycle

Movement in the atmosphere

- **Enter of Sulphur into the atmosphere**: From the lithosphere, the Sulphur enters into the atmosphere through different routes such as weathering of rocks, volcanic activity, soil dust, industrial activity and Sulphur reducing bacteria activity. Aerosols of sea water, deep sea hydrothermal vents, dimethyl sulfide gas produced by the marine algae are the routes of Sulphur entry into the atmosphere.
- **Reaction with water:** The oxides of Sulphur react with water droplets in the atmosphere to form droplets of sulphuric acid. This reaches the earth as acid rain or dry deposition.

Human Impact on Sulphur Cycle

Burning of Fossil Fuels, purification of Sulphur containing metallic ores releases larger amounts of hydrogen sulfide and Sulphur dioxide gas into the atmosphere. This increases the phenomena of acid rain which is harmful to plants, animals and even monuments.

Ecological Succession

Ecological succession is the gradual process through which biological communities develop and establish in an area over time. It denotes the change in species composition and community structure and function over time. Furthermore, it occurs when a series of communities replace one another until a stable and mature community develops. For example, when an old farm field is abandoned and left alone for many years, it gradually becomes a meadow, then a few bushes grow, and eventually, trees completely fill in the field, producing a forest.

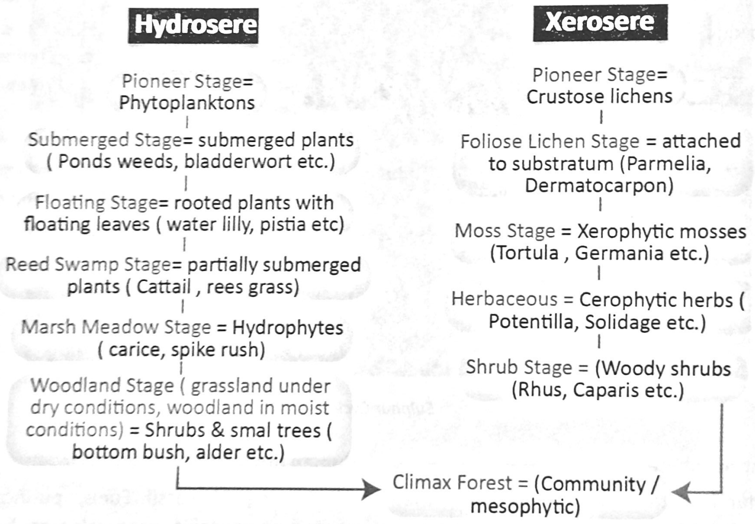
Types of Successional Communities

- **Pioneer Community:** It is the first community to establish itself in a newly created or disturbed environment. The species that make up this community are fast-growing and can tolerate harsh environmental conditions.

Example: Lichens which colonize a bare rocky area.

Lichens are a symbiotic organism. They are made up of a fungus and an alga or cyanobacterium. The lichens are capable of thriving in harsh environmental conditions. They are the first species to establish themselves in bare rocky area. They secrete acids that break down the rock surface. As lichens grow and die, they add organic matter to the soil. This helps other plants to establish themselves in the area.

- **Seral Community:** These are the transitional communities. They form the intermediate stage between a pioneer community and a climax community. In this stage, the food chains and food webs are simple.
  - **Different Types of Seral Community**
    - **Hydrosere**: Succession in aquatic habitat.
    - **Halosere:** Succession starting in saline soil or water.
    - **Xerosere:** Succession in dry habitat.
    - **Psammosere:** Succession initiating on sandy areas.
    - **Lithosere:** Succession on a bare rock surface.
- **Climax Community:** It is the final stage of succession. It indicates that the ecosystem has reached a state of equilibrium and remains relatively stable until disrupted. For example, a mature forest.


Hydrosere
Pioneer Stage= Phytoplanktons
Submerged Stage= submerged plants (Ponds weeds, bladderwort etc.)
Floating Stage= rooted plants with floating leaves (water lilly, pistia etc)
Reed Swamp Stage= partially submerged plants (Cattail , rees grass)
Marsh Meadow Stage = Hydrophytes (carice, spike rush)
Woodland Stage (grassland under dry conditions, woodland in moist conditions) = Shrubs & smal trees (bottom bush, alder etc.)
Xerosere
Pioneer Stage= Crustose lichens
Foliose Lichen Stage = attached to substratum (Parmelia, Dermatocarpon)
Moss Stage = Xerophytic mosses (Tortula , Germania etc.)
Herbaceous = Cerophytic herbs (Potentilla, Solidage etc.)
Shrub Stage = (Woody shrubs (Rhus, Caparis etc.)
Climax Forest = (Community / mesophytic)

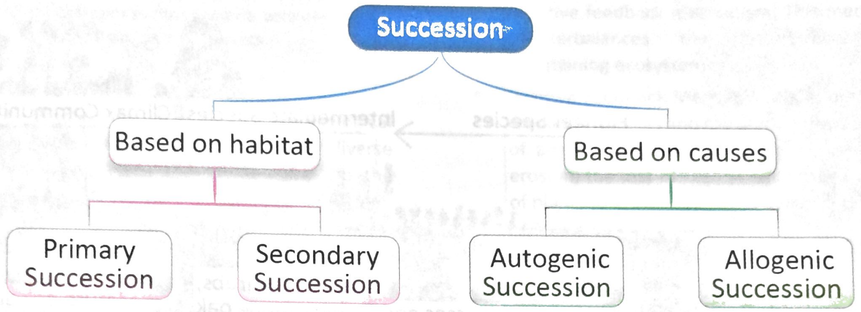
Hydrosere and Xerosere

General Process of Succession

- **Nudation:** *Development of bare area or nudation without any form of life. It may be caused due to several factors like volcanic eruptions, landslides, floods, erosion, earthquake, forest fire, the spread of disease, etc.*
- **Invasion:** *It is the successful establishment of a species in a barren area. The arrival of various species and their settlement in the new or bare area occurs by air, water, etc., known as migration.* Adjustment of establishing species with the prevailing conditions is known as ecesis. Then the individual species are multiplied by reproduction and increase their numbers; by the process called aggregation.
- **Competition and coaction:** After aggregation, the individuals of a species compete with other organisms for food, space, and other resources. The intraspecific and interspecific competition takes place along with interaction with the environment. New invasion by plants and animals takes place.

- **Reaction:** The modification of the environment through the influence of living organisms on it is called reaction.
- **Stabilization (Climax):** The stage at which the final or climax community becomes more or less stabilized for a longer time in that particular environment is known as stabilization.

Types of Succession

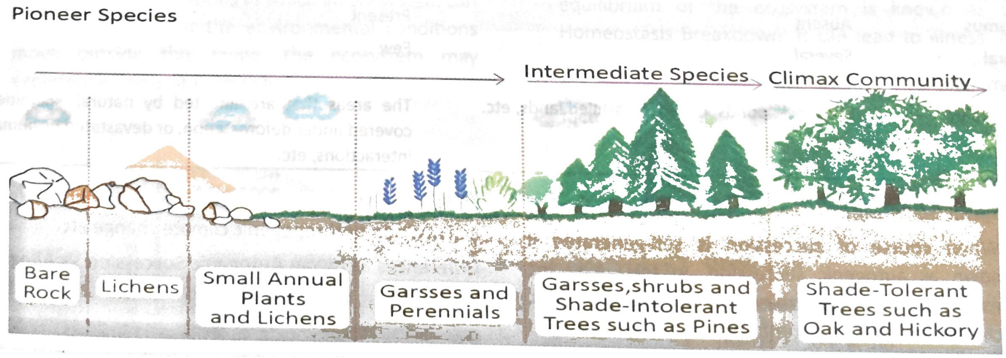


Primary Succession

It occurs in habitats that are devoid of any life, such as newly formed volcanic islands, newly exposed seafloor, sand dunes, newly cooled lava sediments, newly submerged areas, etc.

- At first there is colonization of the habitat by pioneer species, such as lichens and mosses. These species can survive in harsh conditions and can tolerate low nutrient levels.
- Over time, when these species grow and reproduce, they contribute to the accumulation of organic matter. This organic matter contributes to the formation of substratum essential for the growth of other plants.
- Eventually, the habitat becomes more hospitable, and more complex plant and animal communities start inhabiting.

Primary succession is a slow process. It generally takes thousands of years for a biotic community to establish, depending upon the substratum and the climate.


Pioneer Species
Intermediate Species
Climax Community
Bare Rock
Lichens
Small Annual Plants and Lichens
Garsses and Perennials
Garsses,shrubs and Shade-Intolerant Trees such as Pines
Shade-Tolerant Trees such as Oak and Hickory

Primary Succession

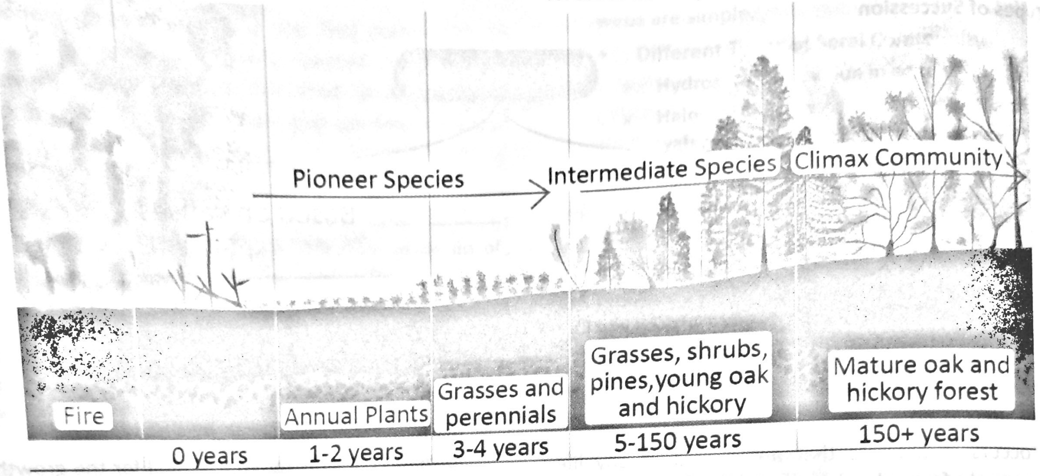
Secondary Succession

It occurs in habitats that have been disturbed or destroyed such as abandoned farmland, burned forests, and areas that have been cleared for mining or logging. However, these habitats still have some soil or organic matter.

- Secondary succession begins with the recolonization of the habitat by pioneer species, such as grasses.
- These species can quickly establish themselves and begin to build up the soil and organic matter.

- Over time, as the soil becomes richer and more stable, complex plant and animal communities start inhabiting.

The process of secondary succession is as some soil or sediment is present. It takes approximately 50–100 years to develop a grassland and 100–200 years for a forest to develop.



Secondary Succession

Difference between Primary and Secondary Succession

Basis	Primary Succession	Secondary Succession
Meaning	It is a type of succession that starts from barren or uninhabited land.	It is the type of succession that occurs in a habitat where life existed previously.
Time	It takes around 1000 or more years	It takes around 50–250 years
Physical Conditions	Conditions are least suitable for the survival of life. Soil is devoid of nutrients, or there is no soil at all.	As life once existed. There is the presence of soil and may also even be some nutrients in the soil.
Humus	Absent	Present
Seral Communities	Several	Few
Examples	Bare rock, ponds, desert, lava-filled lands, etc.	The areas that are affected by natural calamities, covered under deforestation, or devastated by human interactions, etc.

Autogenic Succession

When course of succession is self-generated it is known as autogenic succession. In this case, the succession is mainly determined by internal coactions. The change in both the community and the environment is a result of the activities of organisms. For example, a change in the environment is brought about by plant shade or litter input to soil. This results into change in structure and properties of soil leading to change in species composition with time.

Allogenic Succession

When course of succession is due to external driving forces, it is known as allogenic succession. Examples of external forces include fire, floods, drought, volcanic activity, non-anthropogenic climate change etc.

Differences Between Autogenic Succession Vs Allogenic Succession

Autogenic Succession	Allogenic Succession
Drive as a result of factors within the community.	Drive as a result of factors outside the community.
Biotic components are the primary drivers.	Abiotic components are the primary drivers.
Related to Secondary Succession.	Related to Primary Succession.

Autotrophic and Heterotrophic Succession

- **Autotrophic Succession**: It is a succession in which, initially, the number of Autotrophs (Green Plants) is greater than the number of animals.
- **Heterotrophic Succession**: In this type of succession, the number of Heterotrophs such as bacteria, actinomycetes, and fungi is greater than the green plants.

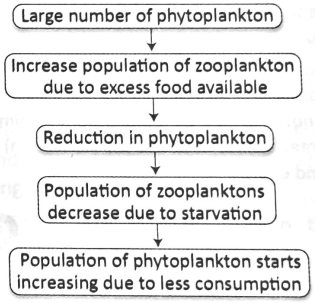
Significance of Succession

- **Promotes Biodiversity:** The process of ecological succession leads to the development of diverse communities of species that are adapted to the changing environmental conditions of an ecosystem.
- **Restores Ecosystems**: Ecological succession plays an important role in restoring degraded or disturbed ecosystems.
- **Helps in Ecological Research**: Study of ecological succession provides scientists valuable insights into the patterns and processes of ecosystem development.

Homeostasis

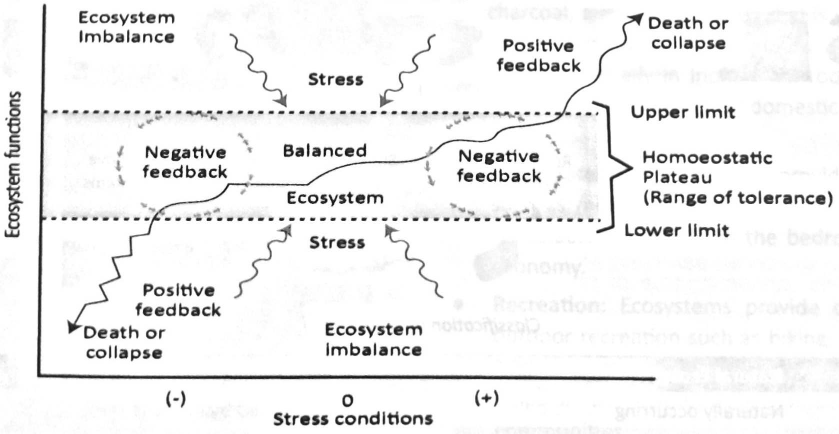
An ecosystem can self-regulate itself. The various components of the ecosystem work together to maintain a stable and balanced environment. The ecosystems have the capacity to resist stress or external disturbances. This property of ecosystems of resisting changes and maintaining a stability is known as homeostasis.

- **Homeostatic Plateau**: It refers to the range of environmental conditions in which an ecosystem can maintain stability. If the environmental conditions move outside this range, the ecosystem may experience stress or even collapse.
- **Feedback mechanisms**: Two types of feedback mechanisms, viz. positive feedback and negative feedback work to maintain homeostasis.
  - **Negative Feedback Mechanism**: Within its homeostatic plateau, the ecosystem uses negative feedback mechanism. This mechanism counterbalances the disturbances helps maintaining ecosystem stability.
  - **Positive Feedback Mechanism:** This mechanism amplifies changes and can lead to destabilization of an ecosystem. For example, in case of soil erosion, the loss of topsoil decreases the ability of plants to grow, which in turn can lead to more soil erosion. This can eventually lead to loss of soil and collapse of the ecosystem.


Large number of phytoplankton
Increase population of zooplankton due to excess food available
Reduction in phytoplankton
Population of zooplanktons decrease due to starvation
Population of phytoplankton starts increasing due to less consumption

Homeostasis in an Aquatic Ecosystem

- **Homeostasis Breakdown:** Any disturbance in the equilibrium of the ecosystem is known as the Homeostasis Breakdown. It can lead to illness, and death and may also cause the extinction of a species. It can be caused by both natural and man-made factors.



Homeostasis

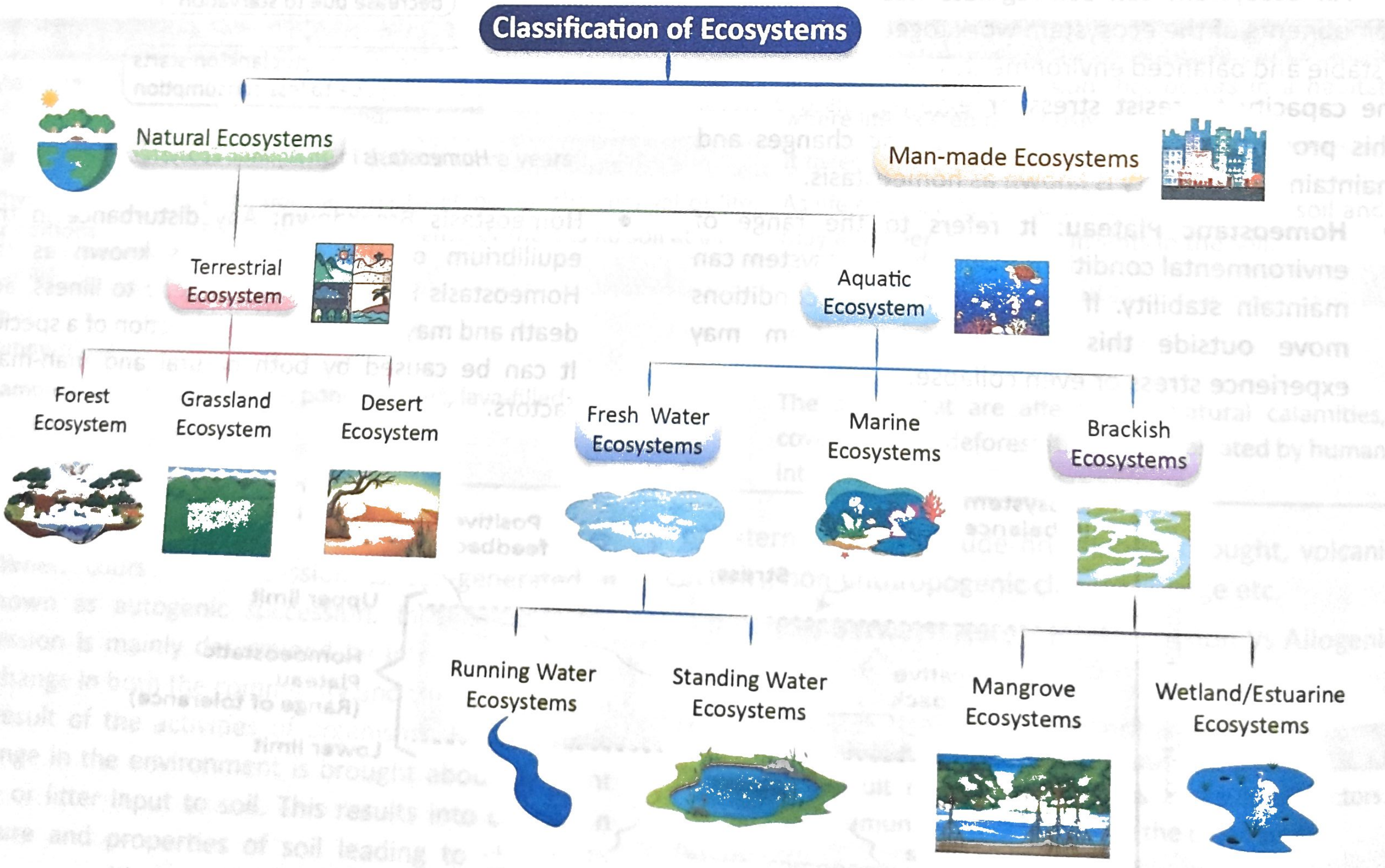
Different Mechanisms of Homeostasis in Organisms

- **Regulate:** It is the maintenance of a relatively stable internal environment despite changes in the external environment. It occurs through positive and negative feedback loops. For example, thermoregulation in humans. In response to external temperature change, the human body maintains constant internal temperature through sweating or shivering.
- **Conform:** It involves adjusting to the external environment rather than regulating internal environment. For example, ectothermic animals (example-reptiles, fishes amphibians) do not regulate their body heat internally and instead rely on external heat sources to regulate their body temperature.
- **Migrate:** It involves the movement of animals to maintain homeostasis. For example, migratory birds. These birds migrate to warmer climatic regions to escape harsh cold winters.
- **Suspend**: It is temporarily stopping or slowing down bodily processes to maintain homeostasis. For example, during hot and dry conditions some animals such as snails enter a state of dormancy (estivation) to conserve water and energy.

TYPES OF ECOSYSTEMS

Ecosystems can be classified into two major types based on the process of their development. Natural Ecosystems are those that have developed through natural processes without any significant human interference. Examples of natural ecosystems include oceans, forests, grasslands etc. The natural ecosystems have by high levels of biodiversity, intricate food webs, and complex interactions between the biotic and abiotic components Natural Ecosystems can be further classified into two major types viz. Terrestrial Ecosystems and Aquatic Ecosystems.

Artificial Ecosystems are those that have been created by humans intentionally or unintentionally. Various human activities such as agriculture, urbanization, and landscaping create artificial ecosystems. Examples of artificial ecosystems include croplands, gardens, parks etc. Artificial ecosystems have simple food webs and lower biodiversity.



Classification of Ecosystems |

Feature	Natural Ecosystems	Artificial Ecosystems
Origin	Naturally occurring	Created by humans
Biodiversity	High	Low

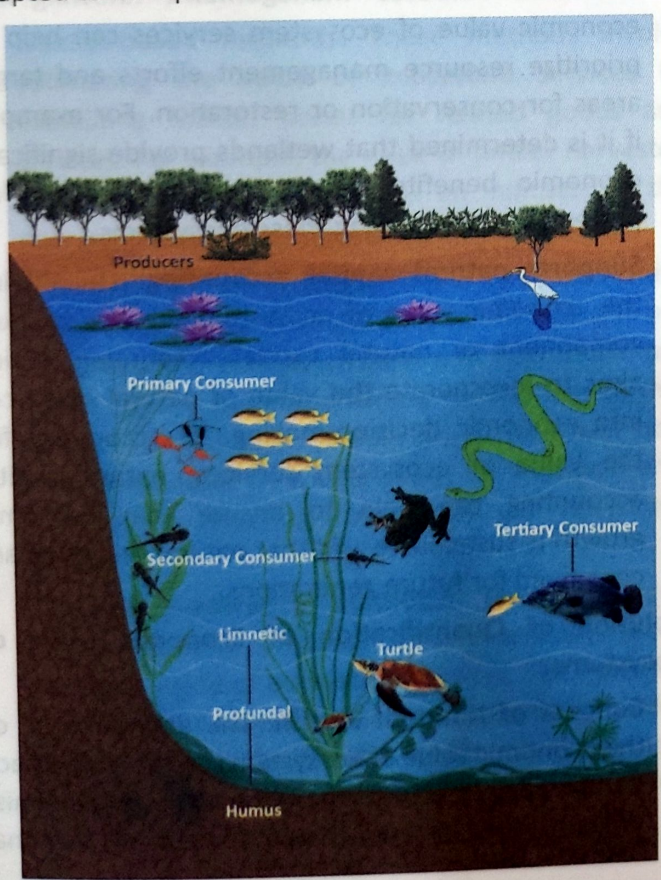
Feature	Natural Ecosystems	Artificial Ecosystems
Species	Native	Often introduced or non-native
Food webs	Complex	Simple
Nutrient cycling	Self-sustaining	Often requires external inputs
Interactions	Ecological interactions are diverse and complex	Fewer ecological interactions
Management	Self-regulating	Often requires human intervention
Resilience	Can adapt to change and recover from disturbances	May be fragile and vulnerable to disturbances
Examples	Forests, oceans, grasslands	Urban parks, golf courses, aquaculture farms

Terrestrial Ecosystems

The ecosystems that exist on land are known as terrestrial ecosystems. They are found in different kinds of environment ranging from rainforests to grasslands to deserts. Each of these ecosystems have unique characteristics and the organisms therein are adapted to specific environmental conditions. For example, in a desert ecosystem, plants and animals have adapted to extreme heat or cold and water scarcity.

Aquatic Ecosystems

Aquatic ecosystems are those ecosystems that exist in water. They can be found in both freshwater and marine environments. Freshwater ecosystems include ponds, rivers, lakes, while marine ecosystems include seas, oceans etc. Similar to terrestrial ecosystems, aquatic ecosystems also have unique characteristics that are adapted to the specific conditions of the environment.



DIRECT AND INDIRECT BENEFITS OF ECOSYSTEM

Ecosystems have several direct and Indirect impacts on Human beings and the surrounding environment, such as:

Direct Benefits

The ecosystem provides us with several valuable and precious resources that make life possible on Earth,

- **Food:** The most significant direct benefit of Ecosystems is to provide food in the form of crops, fish, and wild fruits and vegetables, which sustains the living organisms on the planet.
- **Fiber:** Ecosystems provide fiber in the form of wood, cotton, and other plant materials used for clothing and other textiles. It supports the millions of employments and thousands of industries across the world
- **Medicines:** The ecosystem is a huge treasure full of medicinal values, which supports a wide variety of medicinal plants and other natural products used in traditional medicine and modern pharmaceuticals. Ancient Indian Medicine system is based on these ecosystem-based treatments.
- **Fuel:** Ecosystems provide fuel in the form of wood, charcoal, and other biomass that is used for cooking and heating. In the majority of rural areas across the world, especially in India, even today they are the major source of energy for domestic and commercial purposes.
- **Raw materials:** Ecosystems provide raw materials such as metals, minerals, and oil that are used in manufacturing and form the bedrock of the global economy.
- **Recreation:** Ecosystems provide opportunities for outdoor recreation such as hiking, camping, fishing, and wildlife viewing. It supports local tourism and helps in the economic sustainability of the local communities.

Indirect Benefits

- **Climate regulation:** Ecosystems play a vital role in regulating the Earth's climate by absorbing and storing carbon dioxide and releasing oxygen through photosynthesis. Forests, for example, absorb more carbon dioxide than they release, making them important carbon sinks that help to mitigate climate change.
- **Water regulation:** Ecosystems help to regulate the water cycle through evaporation and condensation and releasing it gradually into streams and rivers. Wetlands, for example, help to filter pollutants and absorb excess nutrients, improving water quality and reducing the risk of flooding.
- **Soil formation and fertility:** Ecosystems play a critical role in soil formation and maintenance of soil fertility. Plants, animals, and microorganisms all contribute to the formation of soil, and the cycling of nutrients helps to maintain soil fertility.
- **Biodiversity:** Ecosystems are home to a vast array of plant and animal species, many of which are used for food, medicine, and other purposes. Biodiversity also plays an important role in maintaining ecosystem stability and resilience.
- **Natural pest control:** Ecosystems provide natural pest control services, such as the use of predator insects to control crop pests, reducing the need for synthetic pesticides.
- **Aesthetic and cultural benefits:** Ecosystems provide aesthetic and cultural benefits, such as scenic beauty and opportunities for spiritual and cultural practices. These benefits can contribute to human well-being and generate economic value through tourism and other activities.
- ***Ecosystem resilience:*** Ecosystems have the ability to adapt and recover from natural and human-induced disturbances, such as fires, floods, and pollution. Maintaining healthy ecosystems helps to ensure their ability to recover from such disturbances.

Quantifying the Economic Value of Ecosystem

Quantifying the economic value of the ecosystem refers to the process of measuring and assessing the monetary value of the goods and services provided by natural ecosystems to human society. These services can include things like air and water purification, carbon sequestration, biodiversity, climate regulation, and nutrient cycling.

Significance

- **Promotes sustainable development:** Quantifying the economic value of ecosystems helps to promote sustainable development by highlighting the benefits that natural resources provide to human society. This information can inform decision-making and policy development that balances economic growth with environmental conservation.
- **Enables informed decision-making:** Understanding the economic value of ecosystem services can help policymakers, businesses, and communities make more informed decisions about the use and management of natural resources. By assigning a monetary value to ecosystem services, it becomes possible to compare the benefits of preserving natural ecosystems with the benefits of converting them for human use.
- **Raises awareness**: Quantifying the economic value of ecosystems raises awareness about the importance of protecting natural resources and conserving biodiversity. By highlighting the economic benefits of ecosystem services, people may be more likely to support policies and practices that promote environmental conservation.
- **Facilitates resource management:** Knowing the economic value of ecosystem services can help to prioritize resource management efforts and target areas for conservation or restoration. For example, if it is determined that wetlands provide significant economic benefits, efforts may be focused on protecting and restoring these ecosystems.
- **Supports natural capital accounting:** Quantifying the economic value of ecosystem services is a key component of natural capital accounting, which aims to incorporate the value of natural resources into economic decision-making. By accounting for the value of ecosystem services, natural capital accounting can help to ensure that economic growth is sustainable and that natural resources are conserved for future generations.

Evolution of Quantification of Economic Value of Ecosystems:

- **Concept of National wealth**: The quantification of the economic value of ecosystems can be traced back to the 18th century, when the English economist William Petty introduced the concept of "national wealth" as the sum of all tangible and intangible assets of a nation, including natural resources.

- **Concept of Rent:** In the early 20th century, the American economist John Bates Clark developed the concept of **"rent,"** which is the payment for the use of natural resources and is based on their scarcity.
- **Concept of Ecosystem Services:** In 1970, the American ecologist Paul Ehrlich introduced the concept of "ecosystem services" in his book "Population, Resources, Environment," and argued that ecosystems provide valuable services to humans, such as pollination, water regulation, and soil formation.
- **Millennium Ecosystem Services:** In 1997, the United Nations Environment Programme (UNEP) launched the "Millennium Ecosystem Assessment.". It was a global assessment of the state of the world's ecosystems and their contribution to human well-being. The assessment provided a framework for quantifying the economic value of ecosystem services and showed that the economic value of ecosystem services is often higher than the economic value of the goods and services produced by human activity.

Methods to Quantify the Economical Value

The are several methods adopted across the world to access the value of goods and services provided by the ecosystem in the monetary term, such as:

- **Market-based methods:** These methods involve estimating the value of ecosystem services by examining market prices for related goods and services. For example, the value of timber harvested from a forest can be used as an indicator of the economic value of the forest.
- **Stated preference methods:** These methods involve asking people how much they would be willing to pay for a particular ecosystem service or how much they would require in compensation for the loss of that service. For example, people might be asked how much they would be willing to pay for improvements in air quality resulting from a particular ecosystem service.
- **Revealed preference methods:** These methods involve analyzing consumer behavior to estimate the economic value of ecosystem services. For example, the economic value of recreational activities provided by an ecosystem can be estimated by examining how much people spend on recreational activities in that area.
- **Cost-based methods:** These methods involve estimating the economic value of ecosystem services by examining the costs of replacing or providing those services through human-made alternatives. For example, the cost of building and maintaining a wastewater treatment plant can be compared to the economic value of wetlands that provide similar water purification services.
- **Benefit transfer methods:** These methods involve transferring economic values estimated from one study or location to another. For example, the economic value of a wetland in one location can be transferred to estimate the economic value of a similar wetland in a different location.

Initiatives

At the Global Level

- **The Natural Capital Project:** It is a collaborative effort by Stanford University, the University of Minnesota, The Nature Conservancy, and the World Wildlife Fund. Their objective is to integrate the economic value of ecosystem services into policy and decision-making through the development of open-source software tools and models.
- **The TEEB (The Economics of Ecosystems and Biodiversity) Initiative:** It is a global initiative launched by the United Nations Environment Programme (UNEP). Its aim is to mainstream the economic value of biodiversity and ecosystem services into policy and decision-making. TEEB produces various resources like reports, guidelines, and tools to help governments and organizations value ecosystem services.
- **The EU Biodiversity Strategy:** It is a strategy created by the European Union. It seeks to restore ecosystems and halt biodiversity loss by 2030. The strategy includes a commitment to value and account for the economic value of ecosystem services in decision-making.
- **The Millennium Ecosystem Assessment:** It was a global initiative launched by the United Nations in 2001. It assessed the state of the world's ecosystems and their contributions to human well-being. The assessment generated various reports and tools for valuing ecosystem services, which have been widely used in research and policy.
- **The Global Alliance for the Future of Food:** It is a coalition of foundations and organizations working towards sustainable and equitable food systems. The alliance supports research and policy development

concerning the economic value of ecosystem services provided by sustainable agriculture and food systems.

- **NCAVES**: It stands for "National Capital Accounting for Valuing Ecosystem Services." It is a program led by the United Nations Statistics Division that aims to promote the implementation of natural capital accounting in countries around the world. Natural capital accounting involves measuring and valuing the benefits that ecosystems provide to society, such as clean water, air, and food, as well as the services they provide, such as carbon sequestration and climate regulation. The NCAVES program also aims to integrate natural capital accounting into national policy and decision-making processes.

At India Level:

- **India is one of the five countries taking part in the NCAVES project** - the other countries being Brazil, China, South Africa, and Mexico. In India, the NCAVES project is being implemented by the MoSPI in close collaboration with the Ministry of Environment, Forest and Climate Change (MoEF&CC) and the National Remote Sensing Centre (NRSC) under the Department of Space.
- **National Biodiversity Act:** The National Biodiversity Act was enacted in 2002 to conserve India's biological diversity and promote sustainable use of its resources. It recognizes the economic value of the ecosystem services and provides for access and benefit sharing.
- **Net Present Value (NPV) of Compensatory Afforestation Fund Act:** NPV is a tool used by CAMPA to assess the economic value of forest land diverted for non-forestry purposes. The NPV calculation takes into account the value of the forest's natural resources, including timber, non-timber forest produce, and other ecosystem services such as carbon sequestration, water recharge, and soil conservation. The calculation also considers the cost of restoring or afforesting an equivalent area of degraded or non-forest land.

State Level:

- **Uttarakhand:** Uttarakhand is the first state in India to implement the Gross Environment Product (GEP). It is an assessment system to measure ecological status. Through its assessment under the ambit of GEP, Uttarakhand concluded that through its biodiversity, gives services to the tune of Rs 95,112 crore per year to the nation.
- **Kerala:** The Kerala State Biodiversity Board has conducted a study on the economic valuation of ecosystem services provided by Vembanad-Kol wetland, one of the largest wetlands in India. The study estimated the economic value of the wetland to be around Rs. 2,200 crores ($292 million) per year.
- **Himachal Pradesh:** The Himachal Pradesh State Biodiversity Board has conducted a study on the economic valuation of ecosystem services provided by the Great Himalayan National Park, a protected area in the state. The study estimated the economic value of the park to be around Rs. 1,300 crores ($173 million) per year.

Challenges in Quantifying the Economic Value of Ecosystems:

There are several challenges in quantifying the economic value of ecosystem services across the world.

- **The complexity of ecosystems:** Ecosystems are complex and dynamic, and their functioning and contributions to human well-being can be difficult to measure and quantify.
- **Lack of data:** There is often a lack of data on ecosystem services, particularly in developing countries, which makes it challenging to estimate their economic value.
- **Heterogeneity of values:** Different stakeholders may have different values and preferences for ecosystem services, which can make it difficult to come up with a single estimate of their economic value.
- **Limited understanding of non-market values:** Some ecosystem services, such as cultural and spiritual values, do not have a market price, making it challenging to estimate their economic value.
- **Uncertainty:** There is often uncertainty around future changes in ecosystem services, which can affect their economic value.
- **Trade-offs:** Valuing ecosystem services can involve difficult trade-offs between different services and between short-term and long-term benefits.
- **Lack of political will:** Valuing ecosystem services can challenge traditional economic models and may not always align with short-term political priorities.

How do we improve the procedure of quantification?

- **Enhance data quality:** A significant challenge in quantifying the economic value of ecosystems is the limited availability of data. To address this issue, investment in monitoring systems, data collection efforts, and research studies are needed to improve the quality and quantity of data on the ecosystem services provided and their associated costs.

- **Incorporate non-market values:** Some ecosystem services, such as cultural values and biodiversity, do not have a market price. It is therefore necessary to develop better methods for including these non-market values in economic analyses. One approach is contingent valuation, which involves asking people how much they would be willing to pay for a specific ecosystem service.
- **Utilize spatially explicit approaches:** Ecosystems' economic value varies across space, with some areas providing more valuable ecosystem services than others. Spatially explicit approaches that map the distribution of ecosystem services and their values across a landscape can be used to account for this spatial variability. Such methods can help to identify areas that are particularly valuable for conservation or restoration efforts.
- **Consider the full range of ecosystem services:** Ecosystems provide a wide range of services, including regulating, provisioning, and cultural services. To accurately assess the economic value of ecosystems, it is crucial to consider the entire range of services provided.
- **Involve stakeholders:** The inclusion of stakeholders in the quantification process of the economic value of ecosystems is essential. Involving stakeholders helps to ensure that the estimated values are relevant and meaningful to those impacted by ecosystem management decisions. Additionally, stakeholder involvement can generate support for ecosystem conservation and restoration efforts.

CHAPTER 3

BIOMES

BIOMES

A region experiencing a particular set of climatic conditions such as temperature and precipitation give rise to a distinctive type of vegetation and associated fauna. Thus, similar types of vegetation spread over large geographic areas having similar climatic conditions. These large geographical areas with more or less uniform set of environmental conditions, flora and fauna are called biomes.

The word "biome" is derived from the Greek word "bios" meaning life. They are also called bioclimatic landscape or biotic areas. The term "biome" was first used in 1916 by **Frederic E. Clements**, an American ecologist, to describe the plants and animals in a given habitat.

There are two main types of biomes: terrestrial and aquatic. Terrestrial biomes are land-based and determined primarily by climate and vegetation. On the other hand, aquatic biomes are those in water (seas, oceans, rivers, wetlands etc.) and are characterized by their physical and chemical properties such as water depth, temperature, salinity, and current flow.

Terrestrial Biomes

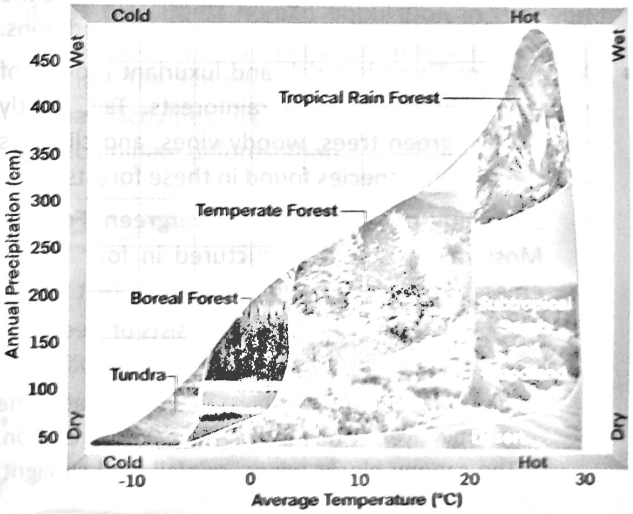
Biomes lack a universally accepted standard categorization. Ecologists and biogeographers have devised diverse classifications for Biomes. In general, Biomes can be classified into- Tropical Evergreen Forests Biome, Monsoon Deciduous forests Biome, Temperate Deciduous Biome, Savannah Biome, Temperate Grassland Biome, Mediterranean Biome, Taiga Biome and Tundra Biome.

Relationship between Climate and Vegetation Type

There is a close relationship between climate and vegetation type. The type of climate in a particular region determines the availability of water, temperature, and other factors that affect plant growth and survival.

The two most important climatic parameters that determine the global distribution of biomes on land are temperature and precipitation and the seasonality of both. Temperature affects the rate of photosynthesis, plant respiration, and overall growth of plants. Different plants have different temperature requirements for optimal growth. Precipitation determines the availability of water for plant growth. Plants require different amounts of water, depending on their size and the type of environment they grow in.

The relationship between climatic conditions and type of vegetation can be understood from the diagram below. The diagram plots mean annual temperature versus the mean average of precipitation for terrestrial biomes. The cold and dry extremes are represented by the tundra biome. While, the high temperatures, high humidity, and abundant rainfall in the tropics result in the tropical rain forest biome characterized by a diverse array of plant and animal life.



Relationship between Climate and Vegetation

> **DO YOU KNOW?**
>
> There are no regions or biomes on Earth where extremely low temperatures and high precipitation occur together. This is due to the fact that the air at very cold temperatures cannot hold enough water vapor to sustain such a climate.

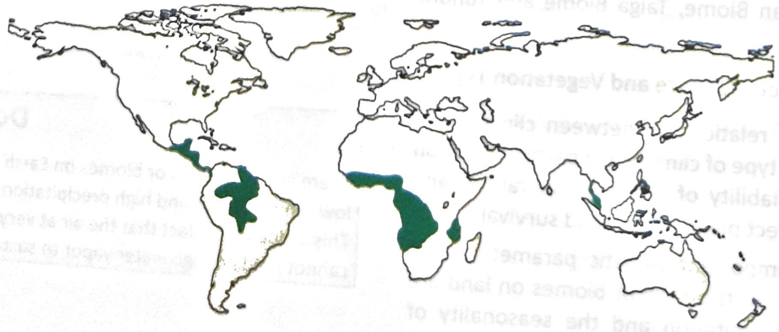
Tropical Evergreen Forests Biome

The Tropical Evergreen Forests Biome is also known as Equatorial Rainforests or Selvas. They are found in the warm and humid tropics where seasonal changes are minimum. Out of all the terrestrial biomes in the world, these forests possess the highest diversity of life and productivity.

- **Geographical Distribution:** The tropical evergreen forests are found between 5° and 10° north and south of the equator. Its greatest range is located in the Amazon Basin (South America), Congo Basin (Africa), and Indo-Malaysian region (Java, Sumatra, Borneo, Malaysia, and Guinea).
- **Climate:** Tropical evergreen forests thrive in a climate that is consistently warm, frost free, and mostly wet throughout the year. The monthly average temperature is always around 27°C. The daily temperature is moderated by cloudiness and heavy precipitation. There is rainfall throughout the year. Average annual precipitation ranges between 150cm-250cm.
- **Soil**: The soils in tropical rainforest biome are poor in nutrients, due to the rapid decomposition of organic matter. Despite their nutrient-poor nature, these soils support a diverse range of vegetation due to the abundant rainfall and warm temperature conditions.
- **Vegetation:** There is a rich and luxuriant growth of vegetation in the tropical rainforests. Tall, tightly spaced evergreen trees, woody vines, and climbers are major plants species found in these forests.
  - **Structure of the Tropical Evergreen Forests:** Most rainforests are structured in four layers: emergent, canopy, understory, and forest floor.
    - **Emergent Layer:** This layer consists of trees over 60 to 80 m in heights. They are widely spaced.
    - **Canopy Layer:** This layer lied beneath the canopy layer. It has a deep layer of vegetation. The canopy blocks winds, rainfall, and sunlight, creating a humid, still, and dark environment below.
    - **Understory Layer:** It is shaded, more humid, and have little wind. In this layer, plants adapt different strategies to capture sunlight. For example, vines climb tree trunks and plants have broad leaves.
    - **Forest Floor:** The forest floor is the darkest of all the layers. In this layer, decomposition of dead leaves take place.

Epiphytes: These are plants that grow on the surface of other plants, without parasitizing them. They derive their nutrients and water without contacting the soil. Hence, they are also known as "air plants". Epiphytes are common in tropical rainforests. Some examples of epiphytes include ferns, lichens, mosses, bromeliads and orchids.

- **Fauna:**
  - Eagles, butterflies, and small gliding mammals are found in the emergent layer.
  - monkeys, tree frogs, snakes, and a large number of insects are found in the canopy layer
  - In the understory layer, Jaguars, numerous amphibians, snakes, and bats are commonly found.
  - Detrivorous animals like ants and termites are found in the forest floor.
- **Human and Tropical Rainforests Biome:** The forests are sparsely populated in terms of life and economy. The majority of primitive people in the forests are hunter-gatherers. The more advanced people practice shifting cultivation. The major threats to tropical rainforests include: shifting cultivation, infrastructure development, construction of dams, mining (for e.g. In Africa, South America, and Indonesia) and commercial logging of tropical hardwoods such as mahogany.



Regions of Tropical Ever

Temperate Rainforests

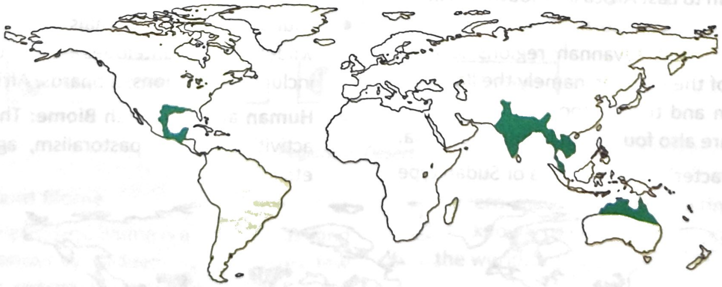
Temperate rainforests can be found along the coasts of certain regions within the temperate latitudes. They are primarily found along the west coast of North and South America, southern Chile, and parts of New Zealand and Australia.

- **Climate:** The climate is moist and cool. Average annual precipitation is above 200 cm. A major difference between tropical and temperate rainforests is that tropical rainforests never experience below freezing temperature, while, some temperate rainforests such as those found in the Pacific Northwest and along the panhandle of Alaska, do experience such temperatures.
- **Vegetation**: Temperate rainforests have both coniferous trees, such as spruce, cedar, and Douglas fir, and broadleaf evergreens like maple and oak. The undergrowth is thick with ferns, mosses, and lichens. Few important species found are the Sitka spruce, western red cedar, and the giant sequoia.
- **Fauna**: Major animals found are black bears, cougars, elk. raccoons and squirrels etc.

Monsoon Deciduous Forest Biome

The monsoon deciduous forest biome is found in the humid tropics where monsoon climate persists. These areas have a marked dry season. As a result, the trees are deciduous (i.e., they shed their leaves in the dry season to survive).

- **Geographical Distribution:** They are found between 10° and 25° latitude and are often located north and south of the world's tropical rainforests. They are most developed in India, Burma, Thailand, Laos, Cambodia, parts of Vietnam, south China, and northern Australia.
- **Climate:** The climate is characterized by seasonality, with distinct wet and dry periods. The average temperature in summers ranges from 27°C to 30°C. The average annual rainfall is 150cm.
- **Vegetation:** The tropical monsoon forests are not as luxuriant as the tropical evergreen forests. The major characteristic features of vegetation are:
  - Trees are mostly deciduous and widely spaced.
  - They do not form a thick canopy.
  - Unlike rainforests, stands of one variety of tree species can be found commonly. For example, sal forests in India, teak forests in China.
  - The commonly found species of trees include teak, sal, bamboo, and eucalyptus.
- **Fauna:** diverse range of animal species, including mammals, birds, reptiles, and insects can be found. Few common species include rhinos, elephants, tigers, langurs, wild buffalo, etc.
- **Human and Monsoon Deciduous Forests Biome:** It has the largest human population in the world. Agriculture is the people's primary economic activity. The biome has largely been affected by human activities like agriculture, urbanization and indiscriminate deforestation.



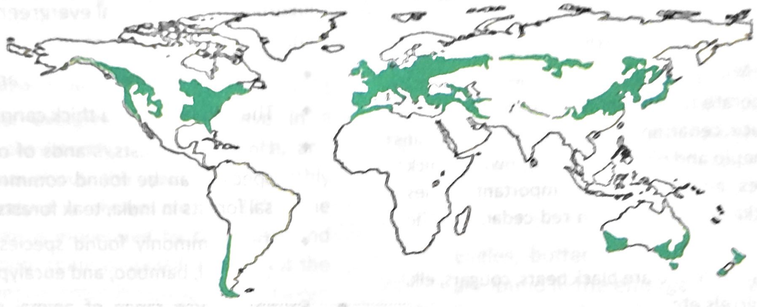
Regions of Monsoon Deciduous Biome

Temperate Deciduous Forest Biome

The Temperate deciduous forest biome occurs throughout the temperate latitudes and is dominated by tall, broad-leaf trees.

- **Geographical Distribution:** It is primarily found in the eastern part of the United States and Canada, most of Europe and parts of China and Japan.
- **Climate:** The climate in the temperate deciduous forest biome is characterized by four distinct seasons. The average yearly temperature is about 10°C. The summer are warm and humid while, the winters are cold and receives snowfall. Precipitation is spread more or less evenly throughout the year. The average rainfall ranges between 75cm to 150 cm.

- **Vegetation:** It is dominated by tall, broadleaf trees that provide a continuous and dense canopy in summer. However, these trees shed their leaves completely during winters. The most common tree species include oak, maple, beech, willow, and birch. Understory vegetation includes shrubs, ferns, and wildflowers.
- **Fauna:** The temperate deciduous forest biome supports a diverse array of animal species and thus the food webs are complicated. Major animals include deer, black bears, raccoons, and grey wolves.
- **Human and Temperate Deciduous Forest Biome:** Humans have altered the temperate deciduous forests through agriculture, logging and urbanization. This has resulted in fragmentation of forest habitats and the displacement of many animal species.

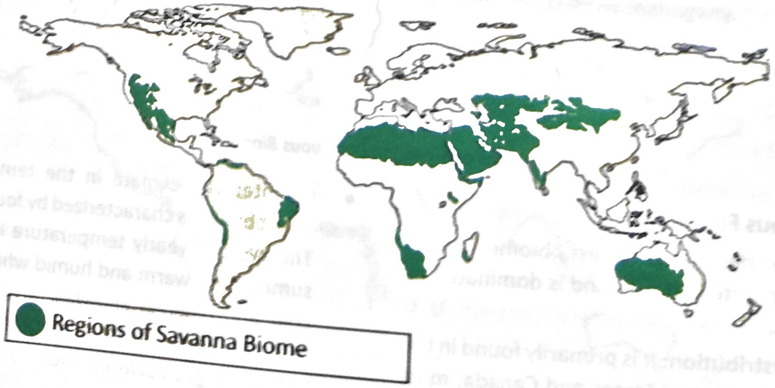


Regions of Temperate Deciduous Biome

Savannah Biome

The Tropical Grassland or Savanna Biome are grasslands with few scattered trees. It is a transitional biome and lies between the tropical rainforests and desert biome.

- **Geographical Distribution:** It is restricted to the tropics and thrives best in Sudan, where the dry and wet seasons are most distinct. The belt extends from West African Sudan to East Africa and southern Africa north of the Tropic of Capricorn. In South America, there are two different savannah regions located north and south of the equator, namely the llanos of the Orinoco basin and the Campos of the Brazilian Highlands. They are also found in northern Australia.
- **Climate:** It is characterized by Savanna or Sudan type of climate with distinct wet and dry seasons. The average annual temperatures range between 20 to 30°C. The average annual rainfall ranges between 25cm to 120cm.
- **Vegetation:** The vegetation is dominated by grasses. The major species of grasses include star grass, Rhodes grass, red oats grass etc. Individual trees or small tree groves are found. Common trees include palms, acacia, baobabs etc.
- **Fauna:** Grazing animals like zebras, buffalos, wildebeest and antelopes are found. Major carnivores include hyena, lions, leopards, African wild dogs etc.
- **Human and Savannah Biome:** The major economic activities include pastoralism, agriculture, tourism etc.

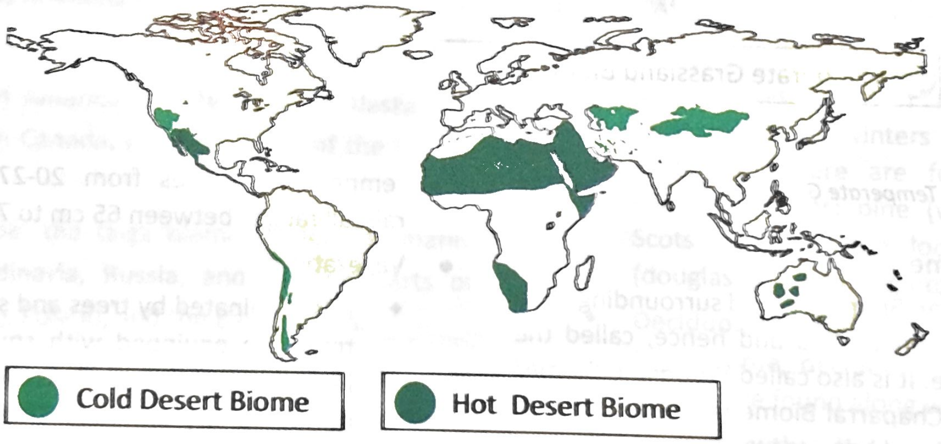


Regions of Savanna Biome

Desert Biomes

Deserts are characterized as climatic regions where the average annual precipitation is below 35cms. Generally, deserts are situated within the latitudes of 30° N and 30° S.

Biome	Hot Desert	Cold Desert
Geographical Distribution	West coasts of continents between 15º and 30º N and S latitudes- Sahara Desert, the Great Australian Desert, the Arabian Desert, the Iranian Desert, the Thar Desert, the Kalahari Desert, and the Namib Desert, Mohave, Sonoran, Californian, and Mexican Deserts in North America, Atacama Desert	Ladakh, Turkestan, the Taklamakan, and Gobi Deserts in Central Asia, the dry basins of the Great Basin in the western United States, and the Patagonian Desert in Argentina.
Climate	High temperatures, with daily fluctuations. Precipitation is low and irregular, often less than 25 cm annually	Extreme temperature variations between day and night. Cold winters and cool summers. Precipitation is low and often in the form of snow or fog.
Vegetation	xerophytes or drought-resistant shrubs. Trees are very rare except where groundwater is abundant in support of palm groups. Important species include cacti, turpentine bush, Ocotillo plant etc.	Sparse vegetation with small shrubs, grasses, and lichens.
Fauna	Adapted to the extreme climate. Major Species include camels, snakes, lizards, and rodents.	Animals such as foxes, coyotes, wolves, and rodents are adapted to the cold temperatures. Birds of prey, such as eagles and hawks, are also common. Large mammals such as bison and reindeer are found in some cold deserts.



Regions of Desert Biome

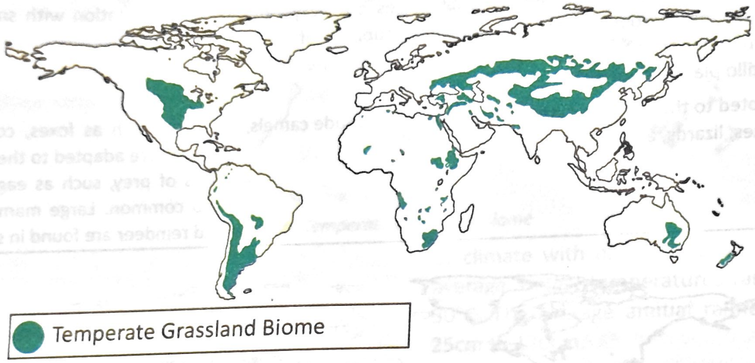
Temperate Grassland Biome

The temperate grassland biome is a type of grassland ecosystem characterized by its deep-rooted grasses, few trees, and distinct seasonal patterns. They are found in various parts of the world, including North America, South America, Eurasia, and Australia.

- **Geographical Distribution:** These grasslands are found mostly at a latitude of 40–60° north and south of the equator. They are located in the interiors of the continents in the northern hemisphere. In the southern hemisphere, they are located on the south eastern margins of the continents. The grasslands are known by different names in different parts of the world.

Name	Region
Steppe	Interiors of Asia and Europe
Prairies	Interior central and western north America (parts of Canada and USA)
Pampas	Argentina, Uruguay and some parts of Brazil
Veldt/ Veld	Eastern part of South African plateau
Downs	Murray Darling basins of South Australia.

- **Climate**: The temperate grasslands of the northern hemisphere are characterized by a continental climate. Extreme summer and winter temperatures are recorded. In the southern hemisphere, the temperate grasslands have a moderate climate as they are located closer to the sea. In the grasslands of both the hemispheres, rainfall is received mostly in summers. Rainfall ranges between 30-85 cm annually. Summer temperatures can reach over 38°C, while in the winters record freezing temperatures.
- **Vegetation:** The natural vegetation of these regions comprises treeless grasslands. These grasses are perennial and belong to the family Gramineae.
- **Fauna:** Major animal species in the temperate grasslands include bison, pronghorn antelopes, wild asses, prairie dogs, etc. A variety of raptors, including hawks and falcons, can be found in the temperate grasslands.
- **Human and Temperate Grasslands:** The temperate grasslands are known for their fertile soils and are used extensively for agriculture. Crops grown in the temperate grasslands include wheat, corn, soybeans, and oats. The grasslands also provide grazing grounds for wide range of animals like sheep, buffalo, bison etc.

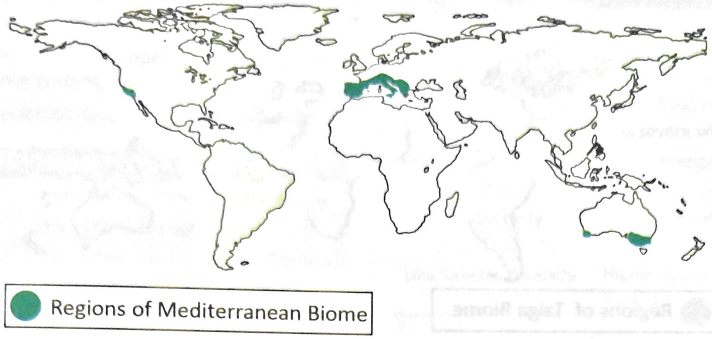


Regions of Temperate Grassland Biome

Mediterranean Biome

The Mediterranean Biome is found surrounding large parts of the Mediterranean Sea and hence, called the Mediterranean Biome. It is also called Woodland Biome/ Shrubland Biome or Chaparral Biome (from the Spanish word "chapa" or scrub oak)

- ***Geographical Distribution:*** *It is found between 30°-40° latitudes in both hemispheres. They are found in western parts of the continents. It includes the European lands bordering the Mediterranean Sea, central and southern California in USA, central Chile in South America, north western coastal lands of Africa bordering the Mediterranean Sea, coastal zones of Western and Southern Australia, western Turkey, Syria, western Israel and Lebanon.*
- **Climate:** It is characterized by a Mediterranean type of climate with warm and dry summers and cool and moist winters. The average temperature in winters ranges from 5-10°C, while the average summer temperature ranges from 20-27 °C. The annual rainfall ranges between 65 cm to 75 cm
- **Vegetation:**
  - It is dominated by trees and shrubs. Shrubs and trees are equipped with small, hard, or thick leaves that resist water loss through transpiration during the dry summers. These plants are called **sclerophylls**.
  - Some important plant species include holm oaks, olive trees, laurels, carob trees, junipers, and cypresses. Herbs like rosemary, thyme, sage, and oregano are also found.
  - The vegetations are often affected by fire. Regrowth occurs from root systems that survived the fire and buried seeds.
- **Fauna**: The biome is home to animals like wild goats, sheep, cattle, mouflon, lynx, wild boar etc.
- **Human and Mediterranean Biome**: The region is significant for fruit cultivation, cereal production, winemaking, agricultural industries, engineering and mining.

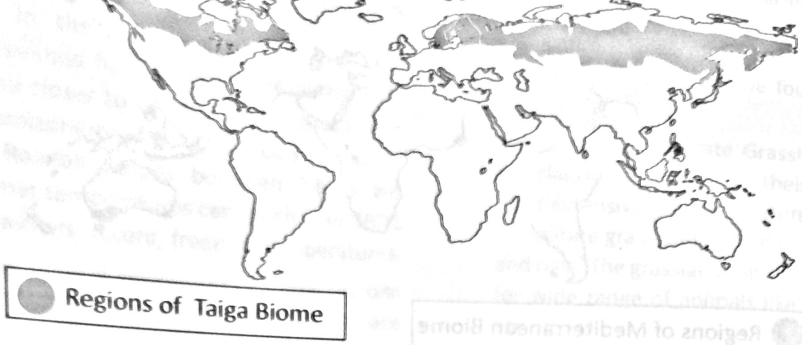


Regions of Mediterranean Biome

Taiga Biome

The Taiga Biome is a high-latitude biome in the Northern Hemisphere. It is also known as the Boreal Forest or the Coniferous Forest Biome. The Taiga Biome merges into the Tundra Biome in the north and temperate deciduous forests or grasslands in the south.

- **Geographical Distribution:**
    - In North America, it extends from Alaska and northern Canada, northern parts of the United States.
    - In Europe, the taiga biome is found primarily in Scandinavia, Russia, and Finland, parts of Germany, Poland, and the Baltic States.
    - In Asia, the taiga biome is found in the Siberian region, parts of Mongolia, China, and northern Japan.
- **Climate:** The Taiga Biome is characterized by subarctic climate with long, cold winters and short, cool summers. The winter temperature ranges bewteen–6 °C and –50 °C. The average summer temperature is around 10°C. Precipitation is low with average rainfall ranging between 30 and 70 cm. Rainfall occurs mainly in the summers.
- **Soil:** Soil in the taiga region is acidic, nutrient-poor, and relatively thin. This is because the cold temperatures and short growing season limit the amount of plant growth and decomposition. This leads to slow buildup of organic matter in the soil. Further, the conifer needles, when decomposed, releases organic acids and make the soil more acidic.
- **Vegetation:**
    - **Coniferous Trees**: The vegetation is primarily of evergreen coniferous trees. These trees form dense forest cover, which is one of the world's richest sources of softwood. Coniferous trees have needles instead of leaves. They don't shed their needles in winters and hence are called evergreen. There are four major evergreen coniferous trees: pine (white pine, red pine, Scots pine, jack pine, lodgepole pine, etc.), fir (douglas fir, balsam fir, etc.), spruce, and larch.
    - **Deciduous Trees:** In the southern margin of the taiga biome, deciduous trees like poplars and birches are found along with conifers.
    - **Undergrowth**: the undergrowth is poorly developed due to highly acidic soil and frost. It mainly comprises of small shrubs, mosses and lichens.
- **Fauna:** Animals in the taiga biome have also adapted to the cold climatic conditions through various adaptive features such as hibernation and migration. Major animal species found in this biome include deer, lynx, elk, moose, wolves etc.
- **Human and Taiga Biome:** The main economic activities in the Taiga Biome include lumbering, mining, and oil and gas exploration. Agriculture in the region is not highly developed. Siberian Samoyeds, Yakuts, and some Canadians, engage in activities hunting, trapping, and fishing.



Regions of Taiga Biome

Tundra Biome

The Tundra biome is located between the Taiga/Boreal Forest biome and the polar ice caps. The word Tundra has been derived from the Finnish word "Tunturia" meaning "barren/treeless hills". In general, there are two types of tundra viz., the Arctic Tundra and the Alpine Tundra.

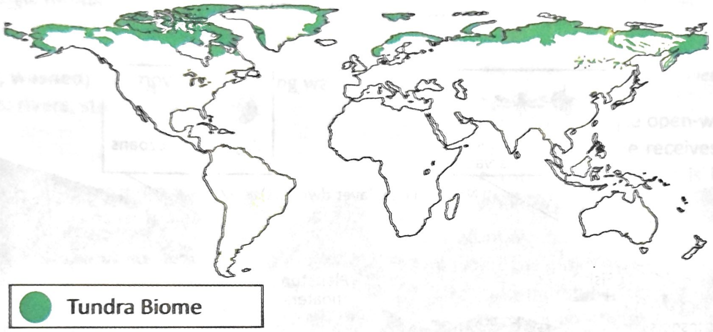
- **Geographical Distribution:**
    - **Arctic Tundra:** It is located near the Arctic Ocean. In North America, it extends from the Bering Strait, through Alaska and northern Canada to Greenland. In Europe, it stretches from northern Scandinavia to Eastern Siberia.
    - **Alpine Tundra:** These are found in the high-altitude mountainous regions in temperate and tropical climatic regions. For example, high altitude regions of Rocky Mountains in North America.
- **Climate:** Tundra regions are characterized by polar climate, with extremely cold and dry winters and very shorts summers. Temperatures in mid-winter (January) can drop to -35°C and are much colder in the interior. In summers, the temperature range between 3°C to 12°C. Precipitation is generally less than 60cm and most of it is in the form of snow.
- **Soil:** The soil primarily consists of permafrost or frozen soil that persists throughout the year. During summer, air temperatures rise above freezing, and a shallow surface layer of ground ice thaws. However, the permafrost beneath remains frozen, keeping the melt water at the surface. These conditions produce a marshy environment for a short time over wide areas. The soil is Tundra region is nutrient poor.
- **Vegetation:** The climate and soil in Tundra region do not promote plant growth. Plants are dwarf and shows prostrate (horizontal) growth along the surface. Major vegetation includes grasses, mosses, lichens, flowering herbs, and shrubs. They mainly grow in summers.
- **Fauna:** The fauna in the Tundra region is also limited by the harsh climatic conditions. Mammals in Tundra include Norway lemmings, arctic hares, arctic ground squirrels, caribou, polar bears, arctic foxes and wolves etc. Seals and walruses are commonly found along the coastlines.

  The animals have also adapted to the cold climate through various mechanisms such as hibernation, migration and morphological and physiological adaptations. Examples of animal adaptations:
    - Animals store fat to sustain and insulate them through the winter.
    - They have thick coats of fur to protect them from severe cold.
    - Some animals hibernate during the long winter months to save energy.
    - Many birds and animals migrate to warmer climes during winter.
    - Tundra insects have also developed adaptations for severe cold climatic conditions. For example, mosquitoes (Aedes nigripes), have a chemical compound that acts as antifreeze. This helps in lowering the freezing temperature in their bodily fluids.
- **Human and Tundra Biome:** The economy of the tundra is primarily confined to the coast. The few people who live in the tundra are semi-nomadic and adapt to the harsh environment. The traditional

inhabitants in the region include Eskimos, Samoyeds and Lapps. The discovery of minerals has prompted new settlements in the region. The biggest threat to the Tundra biome is climate change.

Difference between Arctic Tundra and Alpine Tundra

Arctic Tundra	Alpine Tundra
Near Arctic Ocean	High altitude mountainous regions
Permafrost present throughout year	No permanent permafrost
Poorly drained soils	Well drained soils
Short growing season	Warmer and longer growing seasons
Severe winter	Less severe winter
Lower precipitation	Higher precipitation than Arctic Tundra
Poor productivity	Higher productivity than Arctic Tundra
Low Species Diversity	Higher species diversity than Arctic Tundra



Regions of Tundra Biome

Aquatic Biomes

Approximately 75% of the Earth's surface is covered by global waters, which can be categorized into three types based on their salt content: fresh water (with salt content less than 0.5%), saline water (with salt content greater than 3.5%), and brackish water (with salt content between fresh and saline water).

Classification of Aquatic Organisms

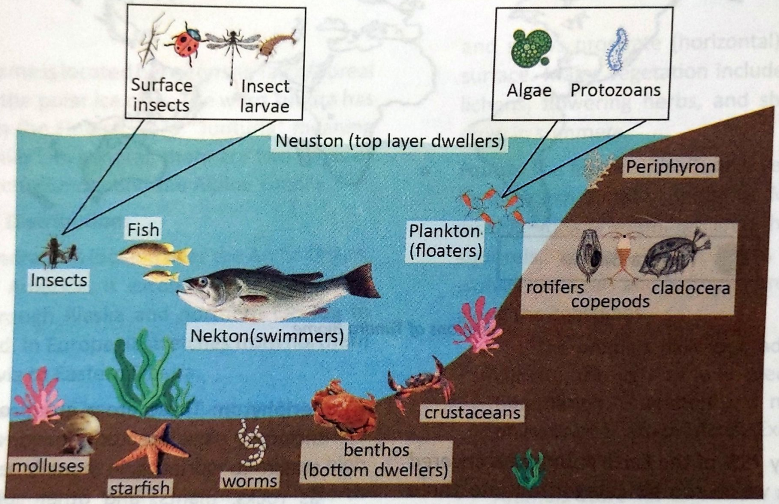
The organisms in the aquatic ecosystem are not evenly distributed, but can be classified into five groups based on their life form or location:

- **Neuston**: These are organisms that live at the air-water interface. They include floating plants and various types of animals. The neustons are adapted to survive in the air-water interface, which is characterized by high levels of surface tension, fluctuating water levels, and exposure to sunlight and air. Examples of neustons include Sargassum, water striders, Whirligig beetles etc.
- **Periphyton**: These are a group of microorganisms, including algae, bacteria, fungi, and protozoa that attach to surfaces in aquatic environments such as rocks, plants, and other submerged surfaces. Examples of periphytons include green algae, diatoms etc.
- **Plankton:** The word Plankton is derived from the Greek word planktos, meaning "wanderer" or "drifter. They are called so as they are unable to swim against currents, tides, or waves. Planktons are of two types:
    - **Phytoplankton:** They are the tiny, plant-like producers and include bacteria and algae that form the base of aquatic food webs. Examples: diatoms, dinoflagellates, cyanobacteria (blue-green algae), and green algae.
    - **Zooplankton**: These are small heterotrophic consumers that drift in the water column. They can be both primary consumers (feeding on phytoplankton) and secondary consumers (feeding on other zooplankton). Examples: Foraminifera, Radiolaria, krill, jellyfish etc.

- **Nekton:** These are swimming aquatic organisms. They can greatly vary in size- from swimming insects to the blue whale. The most important organism in the nekton community are the fishes. Fishes can again be classified into three types:
  - **Demersal fish**: found on or near the bottom of the ocean.
  - **Reef fish:** connected with coral reefs.
  - **Pelagic fish:** live in the pelagic zone of ocean or lake waters, where they are neither close to the bottom nor near the shore
- **Benthos:** live on or near the bottom of a body of water, such as the ocean, sea, lake, or river. Examples include Crustaceans (Lobsters, crabs, and shrimp), Echinoderms (Sea stars, sea urchins) Cephalopods (Squid, octopus etc.)

DO YOU KNOW?

The majority of the carbon dioxide transfer from the atmosphere to the ocean is carried out by phytoplankton. Through photosynthesis, phytoplankton consume carbon dioxide, and the resulting carbon is assimilated into their structure. Most of this carbon is released back into the upper layers of the ocean as phytoplankton are consumed or decomposed after death. However, a portion of carbon di oxide sinks to the deep ocean. According to estimates, phytoplankton transfers about 10 gigatons of carbon from the atmosphere to the deep ocean each year.



Aquatic Organisms

Factors Limiting the Productivity of Aquatic Biomes:

A major difference between Terrestrial Biomes and Aquatic Biomes is that, productivity in aquatic biomes is primarily limited by sunlight and oxygen, while in terrestrial biomes, the productivity is limited by moisture and temperature. The main factors limiting productivity in aquatic biomes are as follows:

- ***Sunlight:*** *It is a major limiting factor in water bodies. It decreases rapidly as it travels through the water column. The water column can be divided into two zones based on the availability of sunlight:*
  - ***Photic Zone:*** *It is the zone or layer where sunlight penetrates and supports photosynthesis. It generally extends up to a depth of about 200 meters in clear waters.*
  - **Aphotic Zone:** It is the zone where sunlight does not penetrate. It is generally below a depth of 200 meters (660 feet) in clear waters.
- **Transparency:** It indirectly affects light penetration and is related to turbidity. Suspended particulate matter, such as clay, silt, etc., can make the water turbid and limit light penetration, thus affecting photosynthetic activity.
- **Temperature:** Due to water's higher specific heat than air, water temperature changes less rapidly than air temperature. The aquatic organisms have lesser temperature tolerance, and even small changes in water temperature pose a greater threat to their survival.

- **Dissolved oxygen**: Unlike in terrestrial ecosystems, where oxygen is part of the atmosphere, in aquatic ecosystems, it is present in a dissolved state. There are several factors that influence the concentration of dissolved in water. These include temperature, salinity, pressure, process of photosynthesis etc.

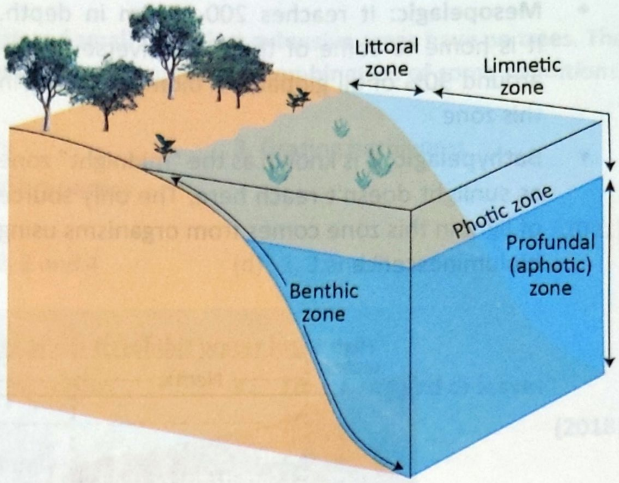
Fresh Water Biomes

Freshwater ecosystems depend upon the input of organic and inorganic matter from the surrounding terrestrial ecosystems. These materials are constantly added to the freshwater ecosystems by the communities growing on nearby land. There are two types of freshwater biomes: Lentic and Lotic. **Lentic (from 'lenis', calm)** are stagnant or still water habitats. Examples: lakes, pools, ponds, wetlands etc. **Lotic (from 'lotus', washed)** are moving or flowing water habitats. Examples: rivers, streams, springs etc.

Freshwater Zones

The four main zones of freshwater ecosystems are the littoral, limnetic, profundal, and benthic zones.

1. **Littoral zone:** This is the shallowest and most productive zone. It is nearest to the shoreline. In this zone, light penetrates to the bottom. It hosts a variety of aquatic plants, algae, and animals such as snails, clams, insects, and fish.



Freshwater zones

2. **Limnetic zone**: It is the open-water area beyond the littoral zone. The zone receives enough sunlight for photosynthesis to occur. It is home to a variety of planktonic organisms.
3. **Profundal zone:** It is the deep, open-water area beyond the point where light can penetrate. It is dark and nutrient-poor. Some deep-water fish and invertebrates are found in this zone
4. **Benthic zone:** It is the bottom of the freshwater ecosystem, where sediment and detritus accumulate. There are a variety of organisms such as snails, clams, worms, and insect larvae, which feed on detritus.

Comparison between Lentic and Lotic Freshwater Biome

Basis	Lentic Freshwater Biome	Lotic Freshwater Biome
Water Flow	No or very little water flow	Constant water flow
Depth	Generally deeper with distinct zones	Generally shallower with less distinct zones
Nutrient Levels	Higher nutrient levels due to stagnation	Lower nutrient levels due to constant water flow
Oxygen Levels	Lower oxygen levels at deeper depths, particularly during summer months	Higher oxygen levels due to constant water movement
Temperature	Surface temperatures can vary widely depending on season	Cooler temperatures due to constant water flow
Biodiversity	It has lower species diversity	It has higher species diversity
Examples	Ponds, lakes	Streams, rivers

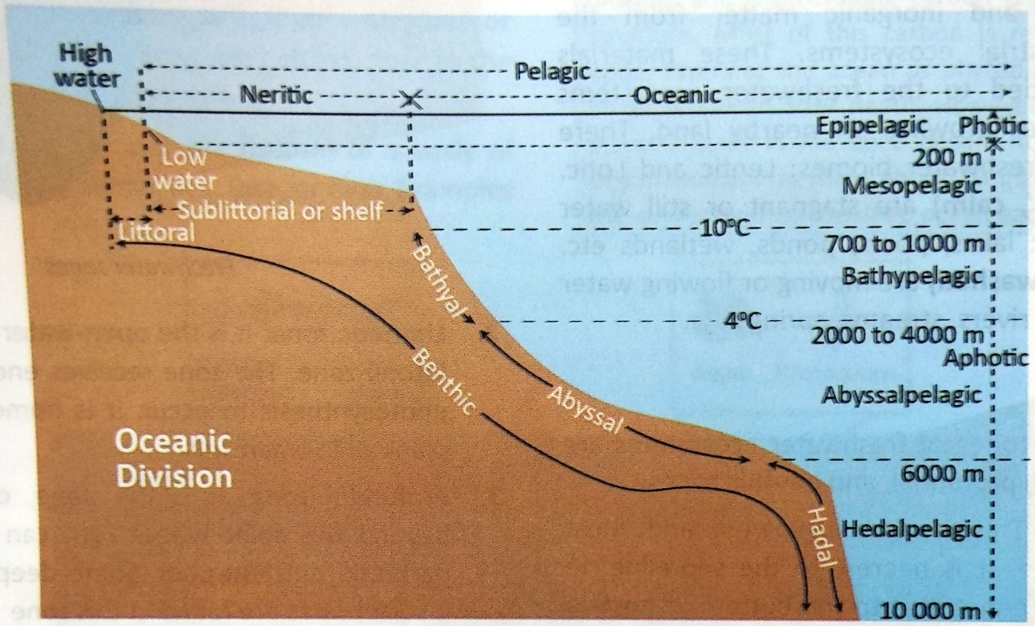
Marine Biomes

Marine biomes are vast bodies of saltwater that cover more than 70% of the Earth's surface. They harbor an immense diversity of species, including various fish species, marine mammals, and plants. The marine biome plays a critical role in regulating the Earth's climate and is an important source of food, medicine, and resources for the human society.

Zones in a Marine Biome

- **Pelagic:** It is also known as the open ocean. It comprises of oceanic water that is not in direct contact with the shore or sea floor. It is subdivided into vertical zones, based on availability of sunlight.
  - **Epipelagic:** It is known as the "sunlit" zone. It begins on the surface of the water and extends to the dark, sunlight-less area were photosynthesis ceases in production.

- **Mesopelagic:** It reaches 200-1000m in depth. It is home to some of the most diverse fishes- around 90% of all global fish biomass occurs in this zone
- **Bathypelagic:** It is known as the "midnight" zone as sunlight doesn't reach here. The only source of light in this zone comes from organisms using bioluminescence
- **Abyssopelagic:** It extends roughly 4,000-6,00 meters and is completely dark. It is home to many organisms that are specialized to live in high pressure, cold, and lightless conditions. The abyssopelagic marine life relies on detritus.



Oceanic Divison

- **Benthic:** It is the lowest level of the ocean and encompasses sediment surface and the water level right above it. It is again into three zones
  - **Bathyal Zone:** It covers the continental shelf.
  - **Abyssal Zone:** It covers vast areas of the ocean with depth ranging between 2000m to 6000m.
  - **Hadal Zone:** It is the oceanic bed of trenches and the depth varies between 6000m to 10000m.

Littoral Zone: It is also known as the intertidal zone. It is the area where land meets the sea. The zone is characterized by a wide range of physical and biological conditions, including exposure to air, water, and sunlight, wave action and variations in temperature and salinity. Organisms in the littoral zone are adapted to survive in these challenging conditions. Examples include: Barnacles and Mussels. These organisms are found attached to rocks, pilings, and other hard surfaces in the littoral zone.

Netric Zone: It is also known as the coastal ocean or sublittoral zone. It is the region of the ocean that extends from the shoreline to the edge of the continental shelf. It is generally shallow, with an average depth of around 200 meters. The netric zone hosts a wide variety of marine life, including fish, invertebrates, and marine mammals.

4

INTRODUCTION TO BIODIVERSITY

Biological Diversity or Biodiversity refers to the diversity of living organisms. It reflects the number, variety and variability of living creatures. Biodiversity includes different species of microorganisms, fungi, plants and animals and the ecosystems they live in. The term biodiversity was first coined by **Walter G. Rosen** and refers to the entirety of genes, species, and ecosystems present in a given region.

Biodiversity varies depending on the geographic location of the ecosystem. It is typically higher near the equator and decreases towards higher latitudes. Similarly, as the altitude increases on a mountain, the biodiversity tends to decrease from lower to higher elevations.

Biodiversity plays a crucial role in maintaining the balance of nature and the functioning of ecosystems. It provides vital ecosystem services such as pollination, nutrient cycling, and climate regulation. However, anthropogenic activities such as habitat destruction, pollution, over-exploitation of resources and climate change are causing a significant decline in biodiversity. This has posed a great threat to the health and long-term wellbeing of the planet.

LEVELS OF BIODIVERSITY

Biodiversity is composed of three interrelated levels, namely genetic, species, and ecosystem diversity, which influence each other. In other words, these levels are interconnected and cannot be separated from each other.

Genetic Diversity

The variety of genes presents within a species can be described as genetic diversity. Genes are the basic units of biological information passed on when living things reproduce. It can be impacted by various factors such as genetic drift, mutation, natural selection, and human activities such as habitat destruction, pollution, and the introduction of invasive species.

- **Significance:** Genetic biodiversity is essential for maintaining the resilience of a species to environmental changes and disease outbreaks. A lack of genetic diversity within a population can increase the risk of inbreeding depression, which can result in reduced fertility, viability, and overall fitness of the population.
- **Example:** Genetic Diversity in humans leads to differences in eye color, height, and susceptibility to different diseases.

Species Diversity

Species diversity is the range of distinct species found in a specific geographical area. It is a measure of the richness and variety of the different kinds of organisms present. High species diversity indicates a healthy and well-balanced ecosystem. On the other hand, low species diversity may indicate environmental stress or disturbance.

Types of Species

Keystone species

A keystone species is a species that plays a critical role in maintaining the structure and function of an ecosystem. Keystone species have a disproportionately large impact on their environment relative to their abundance or biomass. If a keystone species is removed from an ecosystem, the entire ecosystem may change dramatically or even collapse. A keystone species holds the ecosystem together.

- **Significance:** The keystone species regulate populations of prey species and shape their behavior, leading to changes in the vegetation and structure of their habitats.
- **Example:** Sea otters are considered a keystone species in the kelp forests of the Pacific Northwest. They feed on sea urchins, which in turn feed on kelp. Without sea otters, sea urchin populations can explode and overgraze the kelp, leading to the collapse of the entire ecosystem. By keeping sea urchin populations in check, sea otters help maintain a healthy kelp forest ecosystem.

- Other examples of keystone species include beavers, which create wetland habitats that support a variety of species, and wolves.

Umbrella species

An umbrella species is a species that, when protected, indirectly protects many other species and their habitats that share its ecosystem. The term "umbrella" refers to the idea that protecting this single species will have a broad impact on the conservation of other species under its protection. By conserving the umbrella species, we can protect the entire ecosystem and its biodiversity.

- **Significance:** Umbrella species have become a popular conservation strategy because they provide a way to conserve multiple species and their habitats with minimal effort and resources. By focusing on protecting a single species, conservationists can address multiple conservation challenges at once.
- **Example:** If we protect a large predator like a tiger, we are also indirectly protecting the prey species that it feeds on, as well as the habitat that supports its survival. This can result in the conservation of a much larger number of species in the same ecosystem.

Indicator species

An indicator species is a species that can provide information about the overall health and condition of an ecosystem. Indicator species are often sensitive to environmental changes, and their presence or absence can provide insights into the status of other species and the quality of the habitat.

- **Significance:** Indicator species are useful tools for monitoring and assessing the health of ecosystems, particularly when it is not feasible to monitor all species or aspects of the environment. By focusing on indicator species, conservationists can obtain information about ecosystem health and target conservation efforts more effectively.

Species	Indications they give
Algae (seaweeds)	Indicators of heavy metal levels in marine environments
Lichens	These are air quality indicators that are sensitive to sulfur dioxide.
Greasewood	Indicates saline soil
Mosses	Indicates acidic soil
Tubifex worms	Indicate oxygen-poor and stagnant water unfit to drink.

Endemic species

It is a species that is found only in a particular geographic area and is not found anywhere else in the world. These species have limited ranges and are often vulnerable to extinction because they are not found in other areas where they may be protected.

- ***Significance:*** *Endemic species are important because they often play unique ecological roles and may have evolved distinct adaptations to their particular environments. They also represent a significant portion of the biodiversity of a region and contribute to its cultural and economic value.*
- ***Example:***
  - *The lemurs of Madagascar are endemic to the island of Madagascar*
  - *The Galapagos tortoise is endemic to the Galapagos Islands.*

Invasive species

An invasive species is a non-native species that has been introduced to a new environment and has the potential to cause harm to native species and ecosystems. Invasive species can outcompete native species for resources, disrupt natural ecological processes, and alter habitats. Non-native species, commonly known as alien species, generally do not present significant risks and can even have beneficial effects. However, when certain alien species have the potential to cause substantial harm to the environment, economy, or society, they are referred to as "invasive alien species."

- ***Significance:***
  - *Invasive plants can reduce crop yields, increase erosion, and alter soil chemistry. Invasive animals can damage infrastructure, transmit diseases, and prey on native species, leading to declines or extinctions.*

  - Preventing the introduction and spread of invasive species is a critical part of conservation and management efforts. This involves monitoring and controlling the movement of species, educating the public about the risks of invasive species, and implementing policies and regulations to limit their impact.
- **Example:** The Burmese Python is native to Southeast Asia, but has become an invasive species in USA. The snakes are known to prey on a wide range of native species, and have caused declines in several populations.

Flagship species

A flagship species is a species that is selected to represent a broader conservation or initiative. These species are often charismatic and popular, and can help to generate public support and interest in conservation efforts.

- **Types of Flagship Species**
  - **International Flagship Species:** These species are acknowledged worldwide. Examples: Bengal tiger, Giant panda, etc.
  - **Cultural Flagship Species:** These species are associated with different cultures. Example: Bornean ironwood is chosen to represent the Dayak people.
  - **Ecological Flagship Species:** These species symbolize different biodiversity. Example: Malagasy Baobab present in Madagascar.
- **Significance:** Flagship species are used to raise awareness and support for conservation efforts on a broader scale, and can be used to promote conservation initiatives for habitats, ecosystems, or other species.

Foundational species

These are species that play a key role in shaping and maintaining the structure and function of their ecosystem. They are dominant or keystone species that have a significant impact on the distribution and abundance of other species in their environment.

- **Significance:** Because of their key role in ecosystem function, foundational species are often the focus of conservation efforts. Protecting and restoring these species can have positive impacts on the entire ecosystem, as well as the human communities that depend on them for resources and services.
- **Example:** Kelp is a foundational species in many marine ecosystems, providing habitat and food for a wide range of marine species. Beavers are an example of a foundational species, as they create dams that alter the flow of rivers and create wetland habitats that support a diverse range of species.

Priority Species

It is a term used by WWF solely for the purposes of planning and simple communication. They can either be a flagship or a keystone species and are chosen to represent an ecoregion or region.

Criteria for Species to be considered priority species:

- Species that are integral to a food chain, without which, it may collapse.
- Species that help to develop and strengthen habitats.
- Species that indicate high needs of conservation practices
- Species exploited for commercial practices
- Species important to specific cultures

Ecosystem Diversity

Ecosystem diversity relates to the variety of distinct biological communities or ecosystems, such as forests, deserts, lakes, and coral reefs, present in a specific region or globally. As ecosystems evolve, the species that are best suited to the particular environment become dominant. Hence, the nature of the ecosystems also plays a crucial role in determining the extent of biodiversity.

MEASUREMENT OF BIODIVERSITY

Biodiversity can be measured using two major components, i.e., Species Evenness and Species Richness.

Species Evenness:

It is a measure of the relative abundances of species within a community. In general, low evenness implies that only a handful of species are dominant in the region or ecosystem.

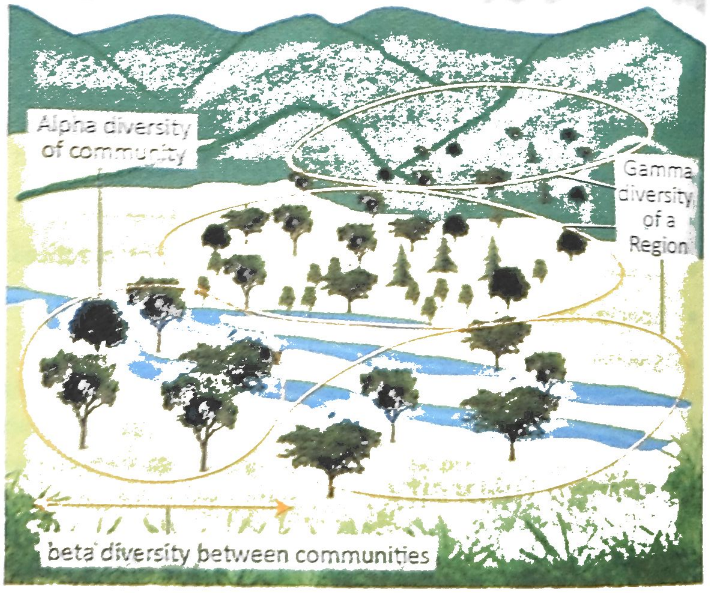
Species Richness:

It is a metric that gauges the number of species present in a particular region or community per unit area.

Biodiversity at Different Scales

Alpha diversity

It refers to the diversity of species present within a specific area or ecosystem. It is measured by the total number of distinct species in the particular ecosystem. Example: Coral reefs are habitats with high levels of alpha diversity. For instance, the Great Barrier Reef in Australia is home to over 1500 fish species and over 400 types of coral.


Alpha diversity of community
Gamma diversity of a Region
beta diversity between communities

Alpha, Beta, & Gamma Diversity

Beta diversity

It measures the change in species diversity between two or more different ecosystems. It is calculated by comparing the number of species that are unique to each habitat and the number of species that are shared between habitats. Example: In a fragmented forest patch, the beta diversity can be measured by comparing the species composition of different forest patches that may have different sizes, shapes and degrees of isolation.

Gamma diversity

It measures the total diversity of various ecosystems present in a particular region. Example: The Amazon rainforest has high biodiversity. It has an estimated, 40000 plant species, 1300 bird species, 427 mammal species, and 2.5 million insect species. The total gamma diversity of the Amazon Rainforest includes all of these species across the entire area.

EXTENT OF BIODIVERSITY

There are different estimates on the total number of species on Earth. The current estimates range between 2 million and 1 trillion, of which about 2.13 million species have been listed by the IUCN in 2021.

According to a 2011 study. there are around 8.7 million species in the world. 6.5 million species are found on land and 2.2 million (about 25 percent of the total) are found in the oceans.

Kingdom	Number of species (Ocean)	Number of species (Terrestrial)	Number of species (Total)
Animals	2,150,000	5,620,000	7,770,000
Chromists	7400	20,100	27,500
Fungi	5320	605,680	611,000
Plants	16,600	281,400	298,000
Protozoa	36,400	0	36,400
Archaea	1	454	455
Bacteria	1320	8360	9680
Total species	2,210,000	6,540,000	8,750,000

Estimated number of species on Earth from Mora et al. (2011)

Biogeographic Realms

The largest biogeographic division of the Earth's land surface is known as a biogeographic realm. It is based on the distributional patterns of terrestrial organisms. The concept of biogeographic realms was developed by **Miklos Udvardy** in 1975.

There are eight major biogeographic realms, namely **Nearctic Realm, Neotropical Realm, Afrotropical Realm, Australasian Realm, Antarctic Realm, Oceania Realm, Malayan Realm** and **Palearctic Realm**. These realms are then subdivided into bioregions, which are further divided into ecoregions.

List of Biogeographic Realms

Biogeographic Realm	Extent	Type of Vegetation	Fauna
Nearctic Realm	Most of North America, excluding tropical areas of Mexico and Central America.	Temperate and boreal forests, Temperate grasslands, deserts.	Bison, grizzly bear, bald eagle, elk, coyote, rattlesnake etc.
Neotropical Realm	Central and South America, including the Caribbean islands.	Mangrove forests, tropical rainforests, savannas and cloud forests	Jaguar, howler monkey, toucan, sloth, anaconda, parrot etc.
Afrotropical Realm	Southwestern Pakistan, southern Iran, the southern regions of the Arabian Peninsula, the area south of the Sahara Desert in Africa, the island of Madagascar, and the islands in the western part of the Indian Ocean.	Tropical and subtropical forests, savannas, deserts.	Elephant, lion, zebra, gorillas, chimpanzees, baboons, colobus monkeys, etc.
Australasian Realm	New Guinea, New Zealand, Tasmania, Australia, and the eastern region of the Indonesian archipelago	Tropical and subtropical forests, grasslands, shrublands.	Kangaroo, koala, emu, wallaby, platypus, kiwi.
Antarctic Realm	Antarctica and its surrounding waters.	No permanent vegetation, only mosses and lichens.	Penguins, seals, whales, krill, albatross.
Oceania Realm	Pacific Ocean and its islands, including Hawaii and Polynesia.	Tropical and subtropical forests.	Dolphin, turtle, shark, humpback whale, dugong, parrotfish and coral reefs.
Indo-Malayan Realm	Southern reaches of East Asia, the greater part of South Asia, and the area known as Southeast Asia.	Tropical rainforests, mangroves.	Orangutan, tiger, elephant, python, gibbons, crocodile, coral reefs.
Palearctic Realm	Area north of the Saharan Desert in Africa, the area north of the Himalayan Mountains in Asia, the northern region of the Arabian Peninsula, and the entire area of Europe.	Taiga and boreal forests, grasslands and steppes, temperate forests, deserts and alpine vegetation.	Brown bear, lynx, wolf, reindeer, ibex, snow leopard, red pandas etc..

Note: There are two distinct biogeographic realms in the Indian subcontinent: the Himalayan region is represented by the Palearctic Realm, while the remaining subcontinent is represented by the Malayan Realm.

Biodiversity Hotspots

Biodiversity hotspots are regions that contain a high number of species that are both endemic and threatened with extinction. The concept of biodiversity hotspots was first introduced by **Norman Myers** in 1988.

There are currently 36 recognized biodiversity hotspots around the world, which together cover only 2.4% of the Earth's land surface but contain an estimated 77% of all terrestrial plant and animal species.

Qualifying Criteria for Declaration of Biodiversity Hotspot

The Conservation International (CI) introduced the following two strict quantitative criteria, for a region to qualify as a hotspot:

- It must contain at least 1,500 species of vascular plants (> 0.5% of the world's total) as endemics;
- It has to have lost ≥ 70% of its original native habitat.

Around the world, 36 areas qualify as hotspots. They represent just 2.3% of Earth's land surface, but they support more than half of the world's endemic plant species and nearly 43% of endemic bird, mammal, reptile and amphibian species.

List of World Biodiversity Hotpots

Regional Distribution of Biodiversity Hotspots	Biodiversity Hotspots
North & Central America	California Floristic Province Madrean pine-oak woodlands Mesoamerica North American Coastal Plain
The Caribbean	The Caribbean Islands
South America	Atlantic Forest Cerrado Chilean Winter Rainfall-Valdivian Forests Tumbes-Choco-Magdalean Tropical Andes
Europe	Mediterranean basin
Africa	Cape Floristic Region Coastal Forests of Eastern Africa Eastern Afromontane Guinean Forests of West Africa Horn of Africa Madagascar and the Indian Ocean islands Maputaland-Pondoland-Albany Succulent Karoo
Central Asia	Mountains of Central Asia
South Asia	Eastern Himalayas Indo-Burma, Bangladesh, India and Myanmar Western Ghats and Sri Lanka
Southeast Asia and Asia Pacific	East Melanesian Islands New Caledonia New Zealand Philippines Polynesia-Micronesia Eastern Australian temperate forests Southwest Australia Sundaland, Indonesia and Nicobar Islands of India Wallacea of Indonesia
East Asia	Japan Mountains of Southwest China
West Asia	Caucasus Irano-Anatolian

These are the unique areas in the rich in biodiversity and provide crucial ecosystem services and are considered critical for conservation and restoration efforts. The Hope Spot initiative is led by **Mission Blue,** a non-profit organization founded by **Dr. Sylvia Earle** in 2009.

- **Identification, Nomination and Criteria:** Hope Spots are identified and nominated by local communities, scientists, and organizations, and are finally recognized by the Mission Blue Foundation. They are designated based on four important pillars, viz.
  - **Species diversity:** The area should contain a high number of species, including threatened and endemic species.
  - **Threats:** The area should be facing significant threats such as overfishing, climate change, pollution, or habitat destruction.
  - **Ecological function:** The area should be ecologically significant, supporting critical ecological processes and providing ecosystem services such as carbon sequestration, nutrient

cycling, and coastal protection.

  - **Social and economic value:** The area should have social and economic value for local communities and/or the wider public, such as supporting fisheries, recreation, tourism, or cultural practices.

- **Hope Spots across World:** According to the official site of Mission Blue, there are 151 Hope spots around the world.
- **Hope Spots in India:** There are two hope spots in India- Andaman and Nicobar Islands and Lakshadweep Islands.

SIGNIFICANCE OF BIODIVERSITY

- **Food Supply and Biodiversity:** Biodiversity provides the raw materials for agriculture, aquaculture etc. and is critical for food security. A diverse range of crops and livestock helps ensure that food production is resilient to environmental changes and disease outbreaks. For example, the diversity of wheat and rice varieties has helped to ensure that these staple crops are resistant to diseases and pests.

DO YOU KNOW?

Of an estimated 80,000 edible plants for humans, only 150-200 are used by humans. Only three crops (rice, maize and wheat) contribute nearly 60 percent of calories and proteins obtained by humans from plants

- **Medicines and Biodiversity:** Biodiversity is a valuable source of medicines. Different products that are used in the development of pharmaceutical drugs and other therapeutic treatments are derived from the natural environment.

Drugs derived from plants and other organism

Drug	Plants/Organisms	Uses
Quinine	Cinchona tree	Used to treat malaria
Morphine	Opium poppy	Used to relieve severe pain
Penicillin	Fungus Penicillium	Used to treat bacterial infections
Digitalis	Foxglove plant	Used to treat heart conditions
Ergotamine	Ergot fungus	Used as analgesic
Thymol	Common thyme	Used as antifungal
Atropine	Belladonna	Used as anti-cholinergic

- **Natural Products and Biodiversity:** Biodiversity provides a wide range of natural products Many of the natural products used daily, such as medicines, cosmetics, and food additives, are derived from living organisms found in the environment. Some of the natural products derived from the living resources are as follows:

Products derived from plants and other organisms

Product	Derived From	Uses
Shellacs	Lac insect	Used in making paints, varnishes etc.
Natural dyes	Plant extracts	Used in textiles etc.
Essential oils	Various plants	Used in aromatherapy and other applications
Honey	Derived from bees and their interactions with plants	Used as natural sweetener
Latex	Sap of rubber tree	used in various products including gloves and tires.
Fibers like cotton, silk	Cotton plants, silk worms	Used in textile industry
Chitin	Exoskeletons of crustaceans and insects	Used in medical and industrial applications

- **Biodiversity and Ecosystem Services:** Biodiversity provides a wide range of ecological services which are crucial for the health of the ecosystems and wellbeing of the humans. Some of the important ecological services are as follows:
  - **Nutrient cycling**: Biodiversity helps in cycling of nutrients through ecosystems, which helps to maintain soil fertility and supports plant growth. For example, organisms such as fungi and bacteria decompose dead organic matter, releasing nutrients that can be taken up by plants.
  - **Pollination:** Biodiversity plays an important role in pollination which is essential for the reproduction of many plant species and the production of food crops. Bees, butterflies, and other pollinators visit flowers to collect nectar and pollen, transferring pollen between flowers and allowing for fertilization.
  - **Pest control:** Biodiversity helps in natural pest control, thus reducing the need for chemical pesticides and promotes the health of crops and

other plants. For example, birds and bats feed on insects, reducing pest populations.

- **Water purification:** Biodiversity helps in purification of water through processes such as filtration and nutrient cycling, making water fit for human and animal use. For example, wetlands act as natural water filters, removing pollutants and excess nutrients from water before it enters rivers and streams.
- **Climate regulation:** Biodiversity helps in regulating the climate by storing carbon, producing oxygen, and influencing weather patterns. Forests store large amounts of carbon and produce oxygen through photosynthesis.
- **Soil Formation**: Biodiversity plays a vital role in soil formation. It supports the accumulation of organic matter in the soil, provides essential nutrients and improves soil structure, water-holding capacity, and enhances soil fertility. For example, organisms like earthworms improve soil structure and fertility by burrowing through the soil. This creates channels for air and water to penetrate, and produces casts that contain high levels of nutrients and organic matter.

Biodiversity and Cultural Services: Biodiversity provides a wide range of non-material benefits to humans, including recreational, aesthetic, and cultural services.

- **Tourism and Recreation:** Biodiversity provides for tourism, recreation and educational activities to people. For example, national parks and other protected areas serve as tourist centers. Many biodiversity rich areas provide recreational opportunities like hiking, fishing etc.
- **Aesthetic Services**: Biodiversity provides beauty and inspiration to humans, including through art, literature, and music.
- **Spiritual and Cultural Services**: Biodiversity is central to many cultures, providing spiritual and cultural values and practices. For example, the Bishnoi community of Rajasthan has deep spiritual and cultural connection to the environment and has been practicing environmental conservation for generations.

Biodiversity and Biotechnology

Biodiversity plays a critical role in biotechnology by providing a vast and diverse array of genetic resources that can be used for research and development.

- **Genetic diversity:** Biodiversity provides genetic resources, including genes, proteins, and other biomolecules for research and development. This enables the discovery of new enzymes, metabolic pathways, and other biological processes and in turn helps in the development of new products and processes. For example, enzymes derived from extremophilic organisms (e.g., bacteria living in hot springs) have unique properties. This make them useful in biotechnology applications, such as the production of biofuels and pharmaceuticals.
- **Bio-prospecting:** It is the exploration of natural resources for new compounds and organisms that can be used in biotechnology applications. For example, the anti-cancer drug Taxol was first discovered in the bark of the Pacific yew tree. It is now produced using a semi-synthetic process.
- **Bioremediation:** It is the use of biological systems and organisms to clean up environmental pollutants and contaminants. Biodiversity provides microorganisms that can break down pollutants, such as heavy metals, pesticides, and hydrocarbons. For example, some bacteria and fungi have the ability to degrade petroleum products. They are used in bioremediation projects to clean up oil spills in marine and terrestrial environments.

BIODIVERSITY LOSS

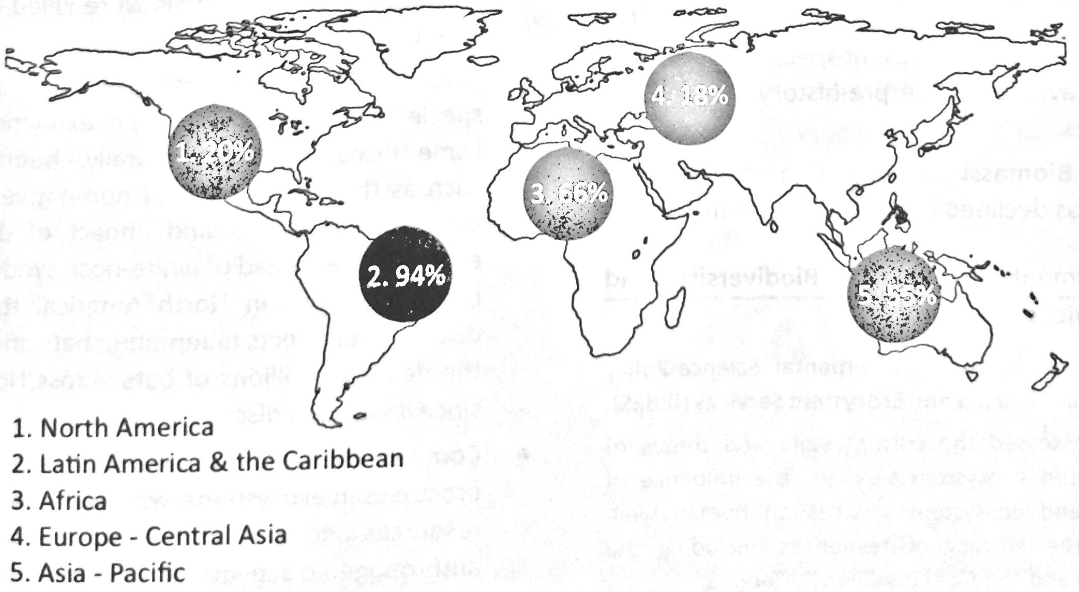
Biodiversity loss is the decline in the variety and number of species in an ecosystem over time. It has become a significant environmental issue as numerous species are becoming endangered or extinct due to human activities such as over exploitation, habitat destruction and human-induced climate change.

Extent of Biodiversity Loss

Global

Key Findings of the Living Planet Report 2022:

- **Average Decline in Species Population:** There has been an average decline of 69% in monitored wildlife populations around the world between 1970 and 2018.
- **Trend by Region:** Latin America has shown the greatest regional decline in average population abundance (94%).
- **Trend by Biome:** the most significant declines in population have occurred in freshwater ecosystems, where populations have declined by an average of 83% since 1970.
- **Major Drivers of Biodiversity Loss:** The major direct driving forces for the degradation of terrestrial, freshwater and marine systems are changes in land and sea use, the overexploitation of plants and animals, climate change, pollution and invasive alien species.



Biodiversity loss by Region

Living Planet Report

- It is a **biennial report** published by the **World Wildlife Fund (WWF).**
- It provides an overview of the state of the world's ecosystems and the species that inhabit them.
- The report is based on the **Living Planet Index.** The index measures world's biological diversity based on population trends of vertebrate species from terrestrial, freshwater and marine habitats. In the 2022 report, 31,821 populations across 5,230 species were included.
- It is important to note that the index does not measure the following:
    - Number of species lost
    - Number of populations or individuals that have been lost
    - Number or percentage of species or populations that are declining
    - Number of extinctions

Key Findings of the Global Assessment Report on Biodiversity and Ecosystem Services, 2019

- **Condition of Ecosystem:** Natural ecosystems have declined by 47% on average, relative to their earliest estimated states.
- **Species Extinction Risk:** Approximately 25% of species are already threatened with extinction in most animal and plant groups studied.
- **Ecological Community:** Biotic integrity (the abundance of naturally present species) has declined by 23% on average (since pre-history) in terrestrial communities.
- **Decline in Biomass:** The global biomass of wild mammals has declined by 82% since pre-history.

Global Assessment Report on Biodiversity and Ecosystem Services

- *It was released by* ***Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).***
- *The report assessed the current state and trends of biodiversity and ecosystem services, the influence of biodiversity and ecosystem services on human well-being, and the efficacy of responses, including the Strategic Plan and the Aichi Biodiversity Targets.*

IPBES Assessment Report on wild species

- Released in 2022, the report stated that about 50,000 wild species globally can meet the needs of billions of people.
- It categorized five different categories used for wild species viz. fishing, gathering, logging, terrestrial animal harvesting.

India

According to the Centre for Science and Environment's (CSE) report entitled **'State of India's Environment in Figures 2021,**

- Over 90% of the area under the biodiversity hotspots in India have been lost.
- The Indo-Burma hotspot is the worst affected and has lost 95% of its vegetation area
- 25 species have also become extinct in the four hotspots of India.
- In India, 1,212 animal species are monitored by the International Union for Conservation of Nature (IUCN) in its Red List, and over 12% of these species – 148 – are endangered. Among the endangered species are 69 mammals, 23 reptiles as well as 56 amphibians.

Causes of Biodiversity Loss

Natural causes

- **Natural Disasters**: Natural disasters such as wildfires, floods, volcanic eruptions and cyclones can negatively impact ecosystems and lead to loss of biodiversity. In recent times, human activities such as deforestation and have aggravated the impact of natural disasters. For example, the Australian bushfires (2019-2020) had a devastating impact on biodiversity. An estimated 3 billion animals were killed or displaced due to the wildfire.
- **Disease:** Disease outbreaks can lead to declines in species populations and even extinctions. Though some diseases occur naturally, human activities such as the introduction of non-native species can increase the spread and impact of diseases. For example, the spread of white-nose syndrome among bat populations in North America. It is a fungal disease that affects hibernating bats and has caused the death of millions of bats across North America since it was first discovered in 2006.
- **Competition and Predation:** These are natural processes in ecosystems, with species competing for resources and preying on other species. However, anthropogenic activities such as habitat destruction and the introduction of non-native species can disrupt ecosystems more. For example, the decline in sea otter populations in the Pacific Northwest was due to overhunting in the 19th and early 20th centuries. This led to an increase in sea urchin populations, which overgrazed kelp forests and reduced the diversity of species in the area.

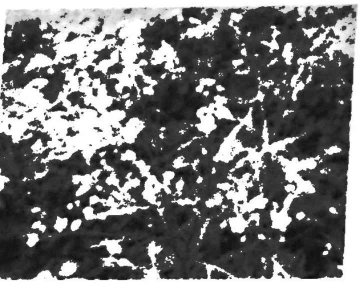
Anthropogenic Causes

Various anthropogenic activities have led to the loss of biodiversity. **Jared Diamond**, a biologist dubbed the four major reasons for biodiversity loss-habitat destruction, over-exploitation of biological resources, alien species invasion and co-extinctions-as the **'evil quartet'.**

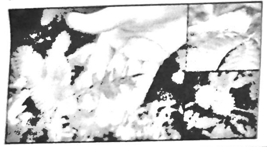
- **Habitat destruction and fragmentation:** Habitat destruction and fragmentation is the primary cause of biodiversity loss. It occurs when natural habitats, such as forests, wetlands, and grasslands, are destroyed due to urbanization, agriculture, industrial activities, infrastructural and developmental activities. Destruction of habitats leads to the displacement and extinction of many species that depend on these habitats Further, fragmentation results in isolated species and loss of genetic diversity, leading to local extinction.
    - For example, according to a 2022 WWF report, 18% of Amazon forests have been wholly lost, and an additional 17% are degraded posing a great threat to its biodiversity. Another example of biodiversity loss due to habitat loss is Borneo where clearance of forests for palm oil production has led to widespread decline of orangutan population.
- **Over-exploitation of biological resources:** Overexploitation of species (overfishing, hunting etc.) for commercial purposes has led to the decline of many species and resulted in destabilization of ecosystems. For example, the African elephant population has declined dramatically due to poaching for their ivory tusks. Steller's Sea cow, passenger pigeons are few examples of species that got extinct due to overexploitation by humans.
- **Alien species invasion:** When alien species are introduced unintentionally or deliberately, some of them turn invasive. This causes decline or extinction of indigenous species and disrupts ecosystem as a whole. For example, the Nile perch introduced into Lake Victoria in East Africa led to the extinction more than 200 species of cichlid fish in the lake.

In India, invasive species have caused local extinctions and altered the composition of entire ecosystems.

List of prominent invasive flora in India

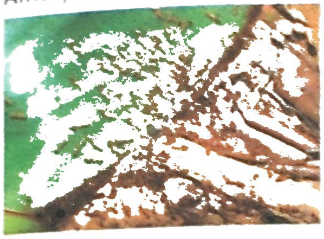
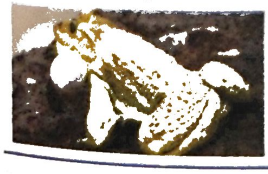
Name (Native to)	Features & Impacted Area
Lantana camara (South America) 	• It was introduced in India in the early 1800s as an ornamental plant. • Lantana forms dense thickets that prevent native plants from growing and can also reduce grazing lands for livestock. It is also toxic to animals • Wildlife Institute of India (WII) found that the co-occurrence of lantana and Pogostemon benghalensis (Bengal shrub-mint, another non-native plant) caused a "significant decline in the richness of native plants and that of palatable plants" in Madhya Pradesh's Kanha Tiger Reserve.
Parthenium/ Congress grass/ Carrot Grass (Tropical North America) 	• It is a fast-growing, drought-tolerant plant and produces large quantities of seeds that are easily dispersed by wind, water, and human activity. • It releases chemicals that inhibit the germination and growth of pasture grasses and other plants. • Further, it can cause severe allergies and respiratory problems in humans and livestock. • It has particularly become a problem in northern and central India.

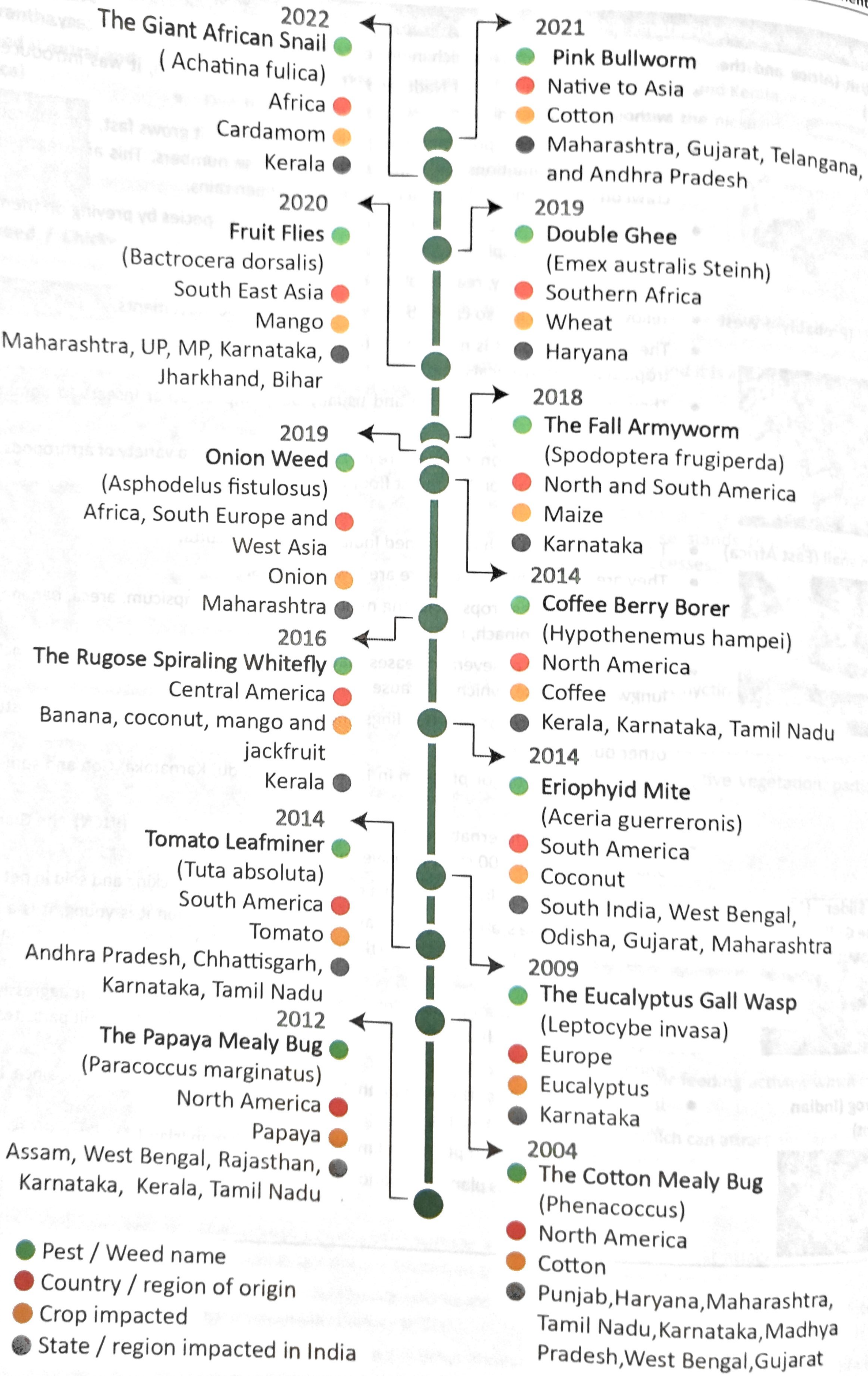
Name (Native to)	Features & Impacted Area
Eucalyptus (Australia) 	• It is a fast-growing tree that was first introduced to India in the late 19th century as a source of timber and to help dry out swamps in some areas. • However, over time, eucalyptus has become naturalized in parts of India and can spread quickly, outcompeting native vegetation and altering the ecological balance of the area. • One of the concerns with eucalyptus in India is that it can consume large amounts of water, potentially depleting water resources in areas where water is already scarce. • Eucalyptus is also known to have allelopathic properties, which means that it can release chemicals that inhibit the growth of other plant species, further reducing biodiversity in the area.
Black Wattle (Acacia) (South East Australia) 	• It has the potential to grow in a variety of soils and can tolerate a wide range of environmental conditions, making it a very aggressive invasive species. • It can form dense thickets that can outcompete native vegetation and reduce biodiversity in the area. • It can also change the soil chemistry, making it more acidic and inhospitable to other plants. • It also the potential to consume large amounts of water, which can further exacerbate water scarcity issues in areas where water resources are already limited. • It has become a major problem in the evergreen Shola forests of the Nilgiris.
Water Hyacinth (Tropical America) 	• It is free-floating, fast-growing aquatic plant introduced in India for ornamental purposes. • It can form dense mats on the surface of water bodies, blocking sunlight and oxygen from reaching aquatic plants and animals. • It also forms a microhabitat for pests and disease-carrying vectors. • It has become a major problem in many water bodies across India, including the Chilika Lake in Odisha and the Dal Lake in Jammu and Kashmir.
Mexican Prickly Poppy 	• It was introduced to India as an ornamental plant. • It can adapt to different environmental conditions, has rapid growth rate, high reproductive capacity, and ability to produce toxins that inhibit the growth of other plants. • The plant can also be toxic to livestock and other animals that graze on it, making it a concern for farmers and ranchers. • It has particularly become a problem in northern and eastern India.
Black Mimosa (Tropical North America) 	• They are found in the Himalayas and western ghats ranges of India. • It forms dense, thorny, impenetrable thickets in wet areas and disrupts indigenous species growth.
Prosopis Juliflora (Mexico) 	• It was introduced in India in 1870s. • It is drought tolerant and an efficient source of fuelwood, thus becoming a source of livelihood for locals. • It has gradually dominated India's arid and semi-arid regions (Gujarat & Rajasthan). • It is a threat to agricultural fields because it competes with native species for groundwater and nutrients • It releases biochemicals which inhibit germination of seeds of nearby flora, thus suppressing the growth of local plants. • It has largely affected the Banni grasslands.

Name (Native to)	Features & Impacted Area
Mikania Micrantha or Mile-a-Minute weed (Central and South America) 	- It was introduced in India after World War II to camouflage airfields, and since then, has adversely affected tea plantations and forests across Assam and Kerala. - Due to the ability to grow rapidly, the plant has earned the nickname of "mile-a-minute" weed. - It is a threat to young plants as it competes for soil nutrients and water, and its dense growth intercepts light.
Billy goat weed / Chickweed (Brazil) 	- It is an herbaceous perennial plant and was introduced to India as an ornamental plant and for medicinal purposes. - It is often one of the first species to colonize degraded areas and so able to prevent other plants from establishing. - Its competitive ability impacts upon native biodiversity and it is also poisonous and can also be toxic to livestock if ingested in large amounts.
Blumea eriantha (Tropical America) 	- It is a fast-growing perennial herb that can reach up to 1.5 meters in height. - It produces numerous small, yellow flowers that are arranged in clusters. It spreads primarily by seed, which is wind-dispersed and can remain viable in the soil for several years. - In areas where it has become invasive, it forms dense stands that can displace native vegetation, reduce biodiversity, and alter ecosystem processes. - It is particularly problematic in disturbed areas such as roadsides, agricultural fields, and abandoned land.
Touch-Me-Not, Sleeping Grass or Mimosa Pudica or Shame plant (Brazil) 	- It undergoes changes in leaf orientation termed "sleep" or nyctinastic movement. - It is distributed throughout in India and has been known to become naturalized and even invasive in some areas where it has been introduced outside of its native range. - It can form dense mats that compete with and displace native vegetation, particularly in disturbed areas such as roadsides, pastures, and abandoned fields.

List of significant invasive fauna in India

Name (Native to)	Features & Impacted Area
Cotton Mealy Bug (North America) 	- It is distributed throughout India especially in North India. - The bugs attack and suck the sap from the leaves and shoot. - The damage caused by Cotton Mealybugs is due to their feeding activity, which can cause stunted growth, yellowing of leaves, and reduced yields. - They also excrete a sticky substance called honeydew, which can attract ants and other insects and can lead to the growth of sooty mold, a fungal disease that can further reduce plant health. - It has become a significant problem in many cotton-producing countries, including India, Pakistan, China.
Papaya Mealy Bug (Mexico and Central America) 	- It is a small polyphagous sucking insect with pest status that attacks several host plants, including economically important tropical fruits (Papaya), vegetables. - Papaya mealybug has caused havoc in agricultural and horticultural crops ever since its first report from Coimbatore in 2007. - It has also been noticed in other states such as Karnataka, certain parts of Andhra Pradesh, Pune in Maharashtra and Malappuram and Thrissur districts of Kerala.

Name (Native to)	Features & Impacted Area
African Catfish (Africa and the Middle East) 	• It is highly nutritious and rich in protein content, is consumed as a delicacy. • Known as Keluthi in Tamil Nadu and African Munshi in Kerala, it was introduced in India without official permission. • The African catfish is popular among fish-breeders since it grows fast, can tolerate adverse water quality conditions and can be raised in dense numbers. This air-breathing fish can crawl on dry ground and can survive in mud between rains. • Being an invasive species, it can destroy the native fish species by preying on them, besides feeding on microscopic zooplankton. • Owing to its adversity, rearing of African catfish is banned in India.
Crazy Ant (Probably West Africa) 	• Yellow crazy ants are so called because of their frenetic movements. • Their original habitat is not known, but they have spread throughout many of the world's tropical and subtropical regions. • They are extremely aggressive and usually out-compete other insects to dominate food resources. • Crazy ants also prey on, or interfere in, the reproduction of a variety of arthropods, reptiles, birds and mammals on the forest floor and canopy.
Giant African snail (East Africa) 	• They are believed to have reached India in 1857 at Calcutta. • They are highly invasive as there are few predators. • The snail damages crops including mulberry, betel vine, capsicum, areca, banana, tomato, vanilla, potato, spinach, radish and tomato. • It is also a carrier of several diseases that can affect both humans and animals, including rat lungworm disease, which can cause meningitis in humans. • The snail can also damage buildings and infrastructure by feeding on plaster, stucco, and other building materials. • It has become a major problem in Kerala, Tamil Nadu, Karnataka, Goa and some parts of North East India. • According to the International Union for Conservation of Nature (IUCN), the Giant African Snail is among the 100 most invasive species in the world.
Red-eared Slider (Mississippi River and the Gulf of Mexico) 	• It was introduced in India through a network of wildlife trafficking and sold in pet shops. • Due to the turtle's attractive coloration and small size when it is young, it is a preferred household pet. However, as the turtle grows bigger in size, pet owners release it into nearby ponds. • With its ability to mature at an early age and reproduce rapidly, the it aggressively takes over its new habitat, harming the native biodiversity. It may also transmit parasites to native aquatic species.
Indian Bullfrog (Indian Subcontinent) 	• It was introduced in the Andaman Islands of India in 2000 and has since become a widespread invasive species. • It eats native fish and reptiles, endangering the Andaman Islands' indigenous fauna. • It commonly inhabits plantations and agricultural fields, preying on small native vertebrates.



2022
🟢 **The Giant African Snail** (Achatina fulica)
🔴 Africa
🟠 Cardamom
⚫ Kerala

2020
🟢 **Fruit Flies** (Bactrocera dorsalis)
🔴 South East Asia
🟠 Mango
⚫ Maharashtra, UP, MP, Karnataka, Jharkhand, Bihar

2019
🟢 **Onion Weed** (Asphodelus fistulosus)
🔴 Africa, South Europe and West Asia
🟠 Onion
⚫ Maharashtra

2016
🟢 **The Rugose Spiraling Whitefly**
🔴 Central America
🟠 Banana, coconut, mango and jackfruit
⚫ Kerala

2014
🟢 **Tomato Leafminer** (Tuta absoluta)
🔴 South America
🟠 Tomato
⚫ Andhra Pradesh, Chhattisgarh, Karnataka, Tamil Nadu

2012
🟢 **The Papaya Mealy Bug** (Paracoccus marginatus)
🔴 North America
🟠 Papaya
⚫ Assam, West Bengal, Rajasthan, Karnataka, Kerala, Tamil Nadu

2021
🟢 **Pink Bullworm**
🔴 Native to Asia
🟠 Cotton
⚫ Maharashtra, Gujarat, Telangana, and Andhra Pradesh

2019
🟢 **Double Ghee** (Emex australis Steinh)
🔴 Southern Africa
🟠 Wheat
⚫ Haryana

2018
🟢 **The Fall Armyworm** (Spodoptera frugiperda)
🔴 North and South America
🟠 Maize
⚫ Karnataka

2014
🟢 **Coffee Berry Borer** (Hypothenemus hampei)
🔴 North America
🟠 Coffee
⚫ Kerala, Karnataka, Tamil Nadu

2014
🟢 **Eriophyid Mite** (Aceria guerreronis)
🔴 South America
🟠 Coconut
⚫ South India, West Bengal, Odisha, Gujarat, Maharashtra

2009
🟢 **The Eucalyptus Gall Wasp** (Leptocybe invasa)
🔴 Europe
🟠 Eucalyptus
⚫ Karnataka

2004
🟢 **The Cotton Mealy Bug** (Phenacoccus)
🔴 North America
🟠 Cotton
⚫ Punjab, Haryana, Maharashtra, Tamil Nadu, Karnataka, Madhya Pradesh, West Bengal, Gujarat

🟢 Pest / Weed name
🔴 Country / region of origin
🟠 Crop impacted
⚫ State / region impacted in India

Major Species Invasions in India

Invasive Species Specialist Group (ISSG)

It is a global network of scientific and policy experts on invasive species. It is organized under the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN).

- It aims to enhance awareness regarding invasive alien species and effective measures to prevent, control, or eliminate them.
- ISSG manages the Global Invasive Species Database. Global Register of Introduced and Invasive Species is also an ISSG led initiative.

Other Factors Causing Biodiversity Loss

Pollution: Environmental pollution is one of the major causes of biodiversity loss. Pollution can directly affect a species by making the environment unsuitable for its survival. It can also affect a species indirectly, by affecting food availability or reproductive performance, consequently reducing population numbers over time. **For example**, the decline on house sparrow population in India has been linked with two factors viz. the pollution caused by electromagnetic radiation from mobile phones and a gradual decrease in nesting sites caused by changes in urban building design.

Climate Change: Changes in temperature, rainfall patterns, and other climate-related factors affect the distribution, survival, and reproduction of many species, leading to their decline or extinction. For example, coral bleaching. As the ocean temperatures rise, corals become stressed and lose the colorful algae that live inside their tissues, which provide them with food and give them their vibrant color. This bleaching event weakens the coral and leaves it vulnerable to disease and death.

Climate Change and Biodiversity Loss- Examples

- In 2014, a single hot day had killed more than 45,000 'flying fox' bats in Australia.
- Due to the absence of fog that is typical to Costa Rican cloud forests, the golden toad became extinct in 1989.
- The **Bramble Cay melomys**, (a small rodent that lived on a single small island between Australia and Papua New Guinea) was declared extinct in 2016. It is the first mammal reported to have got extinct due to human-induced climate change.

Co-extinctions: The extinction of a particular species results in the extinction of other plant and animal species that depend on it for its survival. For example, many plants depend on specific pollinators, such as bees, butterflies, and birds, for their reproduction. When the pollinator species becomes extinct, the plant species that depend on it for pollination can also become extinct. The extinction of the Xerces blue butterfly in California was associated to the decline of its host plant, the coastal dune lupine.

Impact of Biodiversity Loss

Biodiversity loss is a serious issue with numerous and far-reaching impacts on both human well-being and the health of ecosystems. The loss of biodiversity is a threat to the functioning of ecosystems and to the services that they provide to humans, such as food production, air and water quality regulation, and climate regulation.

Ecological Impact

- **Loss of ecosystem services:** Ecosystems provide a wide range of services such as nutrient cycling, air and water purification, climate regulation etc. Biodiversity loss can disrupt these services and lead to negative impacts on human well-being. For example, loss of wetlands can reduce water purification and flood control services, leading to increased risks of natural disasters such as floods and droughts.
- **Accelerated Rate of Species Extinction:** Anthropogenic climate change, habitat destruction, overexploitation of resources, pollution, and introduction of invasive species have accelerated the rate of species extinction. It is estimated that the current rate of species extinction is around 1,000 to 10,000 times rapid the average rate during the last several billion years.
- **Disruption of Food Webs**: The loss of species can disrupt food webs leading to alteration of the predator-prey relationships. This will affect the balance of the ecosystem and lead to eventual collapse. For example, the extinction of bees can have a cascading effect on plants that rely on bees for pollination.
- **Increase in Zoonotic Diseases:** Zoonotic diseases are those that are spread from animals to humans. Rampant habitat destruction has led to increased contact between humans and animals. This has led to a dramatic increase in the transmission of pathogens from animals to humans- a process called **zoonotic spillover.** For example, the increase in Ebola outbreaks in Democratic Republic of Congo has been associated with deforestation and land use changes.

Economic Impact

- **Impacts on Food Security:** Biodiversity loss can have significant impacts on food security, particularly in developing countries that rely heavily on natural resources for food production. Loss of pollinators, soil degradation, and water scarcity can all reduce crop yields, leading to food shortages and increased food prices. In addition, the loss of biodiversity can also affect the nutritional quality of food. For example, the loss of wild fish populations can reduce the availability of essential nutrients such as omega-3 fatty acids.

- **Impacts on Economic Activities:** Biodiversity loss can also have significant impacts on economic activities. For example, the loss of forests can reduce the availability of timber and non-timber forest products, such as fruits, nuts, and medicinal plants. Loss of fish populations can impact commercial fishing, affecting the livelihoods of millions of people around the world.
- **Increased Expenditure on Disaster Management**: Biodiversity loss can increase the frequency and severity of natural disasters such as droughts, floods, landslides, and wildfires. This can lead to increased costs for disaster management and recovery.

Social and Cultural Impacts:

- **Loss of Cultural and Spiritual Values:** Loss of biodiversity can lead to the loss of traditional knowledge, cultural practices, and spiritual values. In addition, the loss of biodiversity can also lead to the loss of cultural and spiritual heritage sites, such as sacred forests and rivers.
- **Increased environmental refugees**: Biodiversity loss can lead to the displacement of indigenous communities who rely on natural resources for their livelihoods. This can result socio-economic marginalization and cultural erosion.
- **Reduced access to ecosystem services:** Loss of biodiversity can lead to reduced access to ecosystem services such as clean water, food, and fuel for vulnerable populations, leading to increased risks of malnutrition, waterborne diseases, and respiratory illnesses.

BIODIVERSITY IN INDIA

India is renowned for its incredible diversity, which encompasses not just its culture, languages, and traditions but also its rich biodiversity. As one of the world's 17 mega-biodiverse countries, India, with its 1.4 billion inhabitants, boasts an impressive array of plant and animal species.

FLORAL DIVERSITY IN INDIA

Floral diversity refers to the variety and abundance of different plant species, within a given geographic area or ecosystem. It encompasses the range of plant species, their genetic variations, and the ecological roles they play in the ecosystem. Some of the key facts regarding floral diversity in India are as follows:

- In term of floral diversity, India ranks 10th in the world and 4th in Asia.
- India is home to around 11% of the world's known diversity.
- In terms of numbers, there are around 45,000 plant species in India, which is approx. 7% of the total plant species in the world.
- Around 28%of plant species are endemic to India. (More than 4045 Angiosperms, 8 Gymnosperms, 196 Pteridophytes, 642 Bryophytes, and 1949 Algae are endemic to India).
- There are around 18,000 flowering plant species in India
- Apart from it, there are 3000-5000 medicinal plant species in India, which are highly valuable for the Indian traditional system of medicine.
- There are also 1300 species of orchids in India, especially found in Sikkim.

Plant Kingdom

Plant Group	Description	No. of Taxa in India	Examples
Algae - Chlorophyceae (Green Algae) - Phaeophyceae (Brown Algae) - Rhodophyceae (Red Algae)	- Chlorophyll-bearing, simple, autotrophic, thalloid and largely aquatic organisms - Ex.- Porphyria, Laminaria, and Sargassum	9008	Porphyria, Laminaria, and Sargassum
Bryophytes	- The plant body is more differentiated than that of algae - They may possess root-like, stem-like or leaf-like structures. -Usually occur in damp, humid, and shaded localities	2800	Mosses, Liverworts
Pteridophytes	- First terrestrial plants to possess vascular tissues- xylem and phloem - Plant body is well differentiated into true root, stem, and leaves	1314	Fern, Salvinia
Gymnosperms	- Plants in which ovules are not enclosed by any ovary wall and seeds are naked	82	Sequoia
Angiosperms - Dicotyledons - Monocotyledons	- The pollen grains and ovules are developed in specialized structures called flowers. - Seeds are enclosed in fruits	21984	Wolffia, Eucalyptus

Plant Kingdom

Cryptogams (Seedless)

Thallophyta

- Thallus is the undifferentiated body
- Vascular system absent
- Example: fungi, lichens & algae

Algae

- These one non-differentiated green plants possessing chlorphyll moist
- Generate their own food

Fungi

- These are non-differentiated non-green plants having absence of chlorophyll
- Grow as saphrophytes on dead or decayed organic matter
- Example- mushroom & moulds
- Found in - western ghats, eastern ghats, western Himalayas

Lichens

- Symbiotic relationship between fungus and algae
- They grow on tree trunks, dead wool or on rock

Bryophyta

- Undeveloped vascular system with improper root and shoot system.
- No movement of substanes across body due to absence of vascular system.
- Grow in moist places
- They are know as amphibians of plant kingdom
- Found in- Eastern Himalyas, north eastern Himalayas western ghats & western Himalayas
- Example- liverworts, mosses, Hornworts etc.

Petridophyta

- Structures are well differentiated like vascular system, stem, root & leaves.
- Can grown in either of the conditions (aquatic/terrestrial)
- found in Himalayas, Eastern and Western Ghats.
- Example- Marsilea, Ferns, Horsetail

Phanerogams (Seed bearing)

Gymnosperms (naked seeds)

- They bear seeds
- Are well differentiated plant body with vascular system.
- Seeds are naked, symbolizing that fruits are not enclosed
- Example – redwood, pines etc.
- Found in- north east, western & eastern ghats and Andaman & nicobar island
- Example - Cycads

Angiosperms (hidden seeds)

- They bear seeds inside fruits
- Are vascular plants possessing flower and fruits
- Example : avacado, pomegranate, mango

Dicotyledons

- Embryo possessing two cotycedons
- Example : gram seed

Mono cotyledons

- Embryo possessing single cotyledons
- Example : wheat, Rice

Factors affecting floral diversity in India

- **Influence of Temperature:** Temperature and its duration impact the growth of plant species. With the changing latitudes, there is variation in temperature regimes, and it leads to distinctive plant types like tropical (Tropical Grassland), temperate (Temperate Grasslands), alpine, etc. **For example,** the tropical rainforests in the Western Ghats region of India are home to diverse plant species like teak, bamboo, and various orchids that thrive in warm and humid climates. In contrast, the alpine regions of the Himalayas support cold-adapted plants such as rhododendrons, junipers, and dwarf willows, which can withstand low temperatures.
- **Influence of Sunlight:** Sunlight provides energy for the photosynthesis process for the production of food. It varies in intensity, and duration across regions which influence the distribution of plants. **For example,** in shaded areas of the Western Ghats, we can find ferns, mosses, and shade-loving epiphytic orchids that have adapted to lower light levels. On the other hand, open grasslands and scrublands in Rajasthan and Gujarat receive abundant sunlight, supporting vegetation like cacti, thorny shrubs, and drought-tolerant grasses.
- **Influence of Moisture:** Water availability is important for all activities in plants like germination of seeds, absorption and transportation of nutrients, etc. Different plants have different water requirements and they can be categorized as Hygrophytes, Mesophytes, Xerophytes, and Tropophytes. **For example,** the dense tropical evergreen forests in the northeastern states of India, such as Meghalaya and Assam, receive heavy rainfall and have high humidity levels, providing ideal conditions for tropical hardwood trees like mahogany and ebony. In the arid regions of Rajasthan, we can find xerophytic plants like cacti, succulents, and thorny bushes that have adapted to survive with limited water resources.
- **Influence of Wind:** Wind conditions influence the distribution of plants in various forms impacting the shape and posture of plants, accelerating transpiration and evaporation processes, and impacting the pollination process. **For example,** the coastal areas of India, particularly along the Arabian Sea and the Bay of Bengal, experience strong sea breezes. This has an impact on the flora, with mangroves, salt-tolerant plants like casuarina, and wind-pollinated plants like coconut palms being common in coastal regions.
- **Influence of Soil:** The physical properties, chemical composition, and biological features of soil influence the distribution of plant species. **For example,** the rich alluvial soils of the Gangetic plains support the growth of crops such as rice, wheat, and sugarcane. Acidic soils in the Western Ghats region provide a favorable environment for the growth of coffee and tea plantations. In sandy coastal regions, we can find plants like casuarina that are adapted to nutrient-poor, well-drained soils.
- **Influence of Physiographic Factors:** Physiographic factors like altitude and relief features also influence floral diversity. For example, the vegetation in the Himalayas can be broadly classified into several zones,

Himalayan Floral Diversity according to Altitude:

Forest Type	Elevation Range	Flora
Tropical Moist Forests	Up to 1,200 meters	Sal, Shisham, Teak, Bamboo
Subtropical Broadleaf Forests	1,200 to 2,000 meters	Oak, Chestnut, Maple, Rhododendron
Temperate Forests	2,000 to 3,000 meters	Blue Pine, Deodar Cedar, Silver Fir, Rhododendron
Subalpine and Alpine Forests	Above 3,000 meters	Dwarf shrubs, Alpine grasses, Juniper, Birch

- **Influence of Biological Factors:** The interaction between microorganisms, animals, and plants also influences floral diversity. For example, the presence of Vallisneria in Keoladeo National Park is primarily attributed to biological factors, particularly its mutualistic relationship with waterfowl.
- **Forest Fires:** It has both positive and negative impacts on the floral diversity in India. On the positive side, it helps in the clearance of dead plant materials and rejuvenates the ecosystem, which allows more sunlight to reach the surface and support further plant growth. On the negative side, it leads to the extinction of various sensitive species of plants from a particular area. **For Example:**
    - **Positive Impact**: The chir pine has serotinous cones that require the heat from a fire to release their seeds and initiate new growth. The fire clears the forest floor, creating space for the regeneration of diverse plant species and promoting floral diversity.

- **Negative Impact**: Loss of various species of plants and trees in the state of Uttarakhand due to forest fires.

Floristic Regions of India

These are regions characterized by the uniform plant species within the region. India has diverse climatic conditions and soil types that support different species of plants and on this basis, India has four major floristic regions,

- **Western Himalayas**: This region consists of high-altitude mountains in the states of Jammu Kashmir, Himachal Pradesh, and Uttarakhand. It is home to various types of trees such as temperate forests, coniferous forests, and subalpine forests, which includes forests of chir, pine, deodar, blue pine, spruce, and silver fir.
- **Eastern Himalayas and North-east India**: It encompasses the states of Arunachal Pradesh, Sikkim, and parts of West Bengal, Assam, Meghalaya, Manipur, Nagaland, and Mizoram. It is mainly characterized by its high rainfall, rich biodiversity, and varied altitudes. It supports various types of forests such as temperate broadleaf forests, subtropical evergreen forests, and bamboo forests. Furthermore, it is home to diverse floral species including orchids, magnolias, ferns, and pitcher plants.
- **Western Ghats**: It is situated along the western coast of India and stretched from the state of Gujarat to Tamil Nadu. The main forest types here are - tropical evergreen forests, moist deciduous forests, and shola-grassland ecosystems. Neelakurinji is an important plant species in the region.
- **Andaman and Nicobar Islands**: These are a group of 572 islands located in the Bay of Bengal and known for their pristine beaches, coral reefs, and dense tropical forests. It supports a wide variety of forests including tropical rainforests, mangrove forests, and coastal vegetation. The flora includes endemic species such as the Andaman Padauk, Andaman bullet wood, and Nicobar palm.

Seaweeds in India

Seaweed, or macro algae, refers to thousands of species of macroscopic, multicellular, marine algae. It includes Rhodophyta, Phaeophyta and Chlorophyta macro algae. They range in colours from red, green, brown and black. They vary in size, from microscopic to large underwater forests.

Seaweed V.S. Seagrass: Seaweeds, classified as algae in the kingdom Protista, are plant-like organisms. They lack features such as a true stem, roots, leaves, and vascular tissues. In contrast, seagrass is a marine flowering plant with distinct stem, roots, and leaves. Seagrass also has the ability to produce fruits and seeds, unlike seaweeds.

Benefits of Seaweed

- **Marine Habitats:** Seaweeds provide crucial habitat and nursery grounds for fishes and other marine organisms. For example, kelp.
- **Climate Change Mitigation:** Seaweeds help in carbon sequestration. They absorb and store large amounts of carbon dioxide from the atmosphere.
- **Health Benefits:** Seaweeds are rich in essential nutrients, vitamins, Omega-3, minerals, and antioxidants. They are also rich in plant compounds like flavonoids and carotenoids
- **Agriculture and Aquaculture**: In agriculture, seaweeds can be used as biofertilizers and soil conditioners. They are also used in aquaculture as feed for fish, shellfish, and other aquatic organisms, promoting their growth and health.
- **Bioremediation**: Seaweeds have the ability to absorb and remove various pollutants, including heavy metals and nutrients, from marine environments.
- **Industrial Applications**: Seaweeds are used in the production of biofuels, bioplastics, and pharmaceuticals. Seaweed extracts are also utilized in cosmetics, skincare products, and food additives.

Species of Seaweed Found in India

- Gracilariaverrucosa in Chilika Lake, Odisha
- Ulva Linza or Ulva prolife rain Chilika Lake, Odisha
- Gracilaria dura in Gujarat
- Ulva Lactuca or Ulva fasciata or Ulva indica all over India coast
- Kappaphycus all over Indian coast

Initiatives taken in India for Promotion of Seaweed Cultivation

Seaweed Mission: It is a mission for commercial farming of seaweeds, and it's processing for value addition towards boosting national economy. It has been launched by Technology Information, Forecasting and Assessment Council (TIFAC). The objectives of the mission are as follows:

- Establishment of model demonstration farms over one hectare for cultivation of economically important seaweeds in nearshore and onshore along the Indian coast.
- Establishment of seaweed nurseries for supplying seed material for large scale farming of economically important seaweeds in the country.

- Establishment and demonstration of processing technologies/recipes for edible seaweeds in line with consumer acceptability or cultural food habits.
- Setting up of processing plant for integrated production of plant growth stimulants (sap) along with industrially important cell wall polysaccharides (polycocolloids) such as agar, agarose, carrageenan and alginates from fresh seaweeds.
- Development of value addition technologies aimed at making high value products for niche markets (personal care, cosmetics, nutraceuticals, feed supplements).

Seaweed Park: India's first seaweed park proposed to be set up in Tamil Nadu. It is an initiative of Union government's Central Salt and Marine Chemical Research. It aims to improve the livelihood of fishermen. Furthermore, it will be implemented under PM Matsya Sampada Yojana.

Natural Vegetation of India

Type	Distribution	Climate	Important Plant Species
Tropical evergreen forests	Western ghats, andaman and nicobar islands, assam	Heavy rainfall more than 250 cm	Rosewood, mahogany, ebony etc
Tropical Semi-Evergreen Forests	Western coast, Assam, lower slopes of the Eastern Himalayas, Orissa, and Andamans	The rainfall is 200-250 cm in a year temperature varies from 24°C to 27°C	White cedar, hollock, and kail
Tropical Dry Evergreen Forests	Visakhapatnam in Andhra Pradesh, Ramanathapuram in Tamil Nadu	the rainfall of 100 cm in a year annual temperature is about 28°C.	neem, jamun and tamarind.
Tropical Moist Deciduous Forests	Himalayas, Jharkhand, West Odisha, and Chhattisgarh,	rainfall between 100-200 cm. annual temperature of about 27°C,	Bamboos, sal, teak, shisham, sandalwood, Khair, Kusum, Arjun, and mulberry
Tropical Dry Deciduous Forests	North India and southern regions of Deccan Plateau.	less rainfall (70 to 100 cm)	teak, neem, peepal, sal, khair, bel, axle wood, palas, laurel etc
Tropical Thorn Forests	Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh, and Uttar Pradesh.	annual rainfall is less than 50 cm (semi-arid regions).	Babul, Palm, Acacia, Kokko, Ber, Neem, Khejri, Palas, etc
Sub-tropical Broad-leaved Hill Forests	Bengal and Assam, Amarkantak, Khasi, Nilgiri, Mahabaleshwar	annual rainfall is 75 cm to 125 cm. average annual temperature is 18°-21°C.	Chestnut, Evergreen oaks, Pines, ash, beech, pines
Sub-tropical Moist Pine Forests	Arunachal Pradesh hilly regions, Manipur Naga Hills, and Khasi Hills.	elevations ranging from 1000 to 2000 metres above sea level	Chir Pine, Oaks and Olives
Sub-tropical Dry Evergreen Forests	western Himalayas	The annual rainfall between 50 and 100 cm.	olive, acacia modesta, and pistacia.
Himalayan Dry Temperate Forests	Ladakh, Lahul, Chamba, Kinnaur, Garhwal, and Sikkim	Precipitation here is low, below 100 cm	Deodar, Chilgoza, oak, maple, ash, parrotia, olive
Himalayan Moist Temperate Forests	Kashmir, Himachal Pradesh, Uttaranchal, Darjeeling, and Sikkim.	Rainfall mostly in the form of snow.	oak, cedar, spruce, maple, walnut, deodar, chestnut
Montane Wet Temperate Forests	eastern Himalayas, Tamil Nadu and Kerala	high rainfall. Moderate temperature in summers but cold in winter.	Oak, Plum, Birch, Deodar, Indian chestnut, magnolia, blue pine, hemlock, chilaune

Type	Distribution	Climate	Important Plant Species
Alpine and Sub- Alpine Forests	western Himalayas and eastern Himalayas.	the region just below the snowline.	species: Larch, subalpinefir, spruce, rhododendron, douglas fir, pinus flexilis
Littoral and Swamp Forests	The deltas of the Ganga, the Mahanadi, the Krishna, the Godavari and the Kaveri	the rainfall varies from 75 cm to 500 cm depending upon the area	Nipa, Sundari, Keora, Agar, Bhendi, sundarban

FAUNAL DIVERSITY IN INDIA

It represents the variety of different species of fauna in a particular region. Like floral diversity, India is also has a rich diversity of fauna. Some of the key facts regarding faunal diversity in India are as follows

- India possesses 7.5% of the world's animal species.
- The total number of animal species in the faunal database is 1,03,258.
- Indian landmass has been classified into 10 bio-geographic zones and the Zoological Survey of India documented the faunal resources in eight bio-geographic zones as-
  - Himalayas with 30,377 species,
  - North-east with 18,527 species,
  - Western Ghats with 17,099 species,
  - Coasts with 11,883 species,
  - Islands with 11,009 species,
  - Semi-arid with 7424 species,
  - Desert with 3346 species and
  - Trans-Himalayas with 3324 species.

Factors affecting Faunal Diversity in India:

- **Influence of Climatic factors**: Moisture, and temperature impact the distribution of animals in India. For example, temperature variations impact animal life as some species like camel are found in high-temperature regions (Rajasthan) and some species like Himalayan Yak are found in low-temperature regions.
- **Influence of Vegetation**: It provides habitat to animal species and also provides supplies of food. Some animals are herbivorous, which is dependent on vegetation and requires plants for their food requirements. For example, the Western Ghats' evergreen forests, specifically the Anamalai Hills in Tamil Nadu, provide a suitable habitat for the lion-tailed macaque. This species is highly dependent on the dense canopy and diverse plant species found in these forests.
- **Influence of Ocean and River Waters**: These provide unique ecosystems that supports a variety of species. For example, the Gulf of Mannar Marine National Park, supports one of the world's richest marine biodiversity. Coral reefs in this region are home to numerous species of fish, sea turtles, dolphins, and whales.
- **Influence of Anthropogenic Factors**: Man-made activities can have both positive and negative impacts. On one hand, deforestation and habitat loss cause the population decline of several species and at the same protective measures and conservation activities lead to better survival chances. For example, decline of Great Indian Bustards due human activities and population increase of Tigers after Project Tiger 1973.

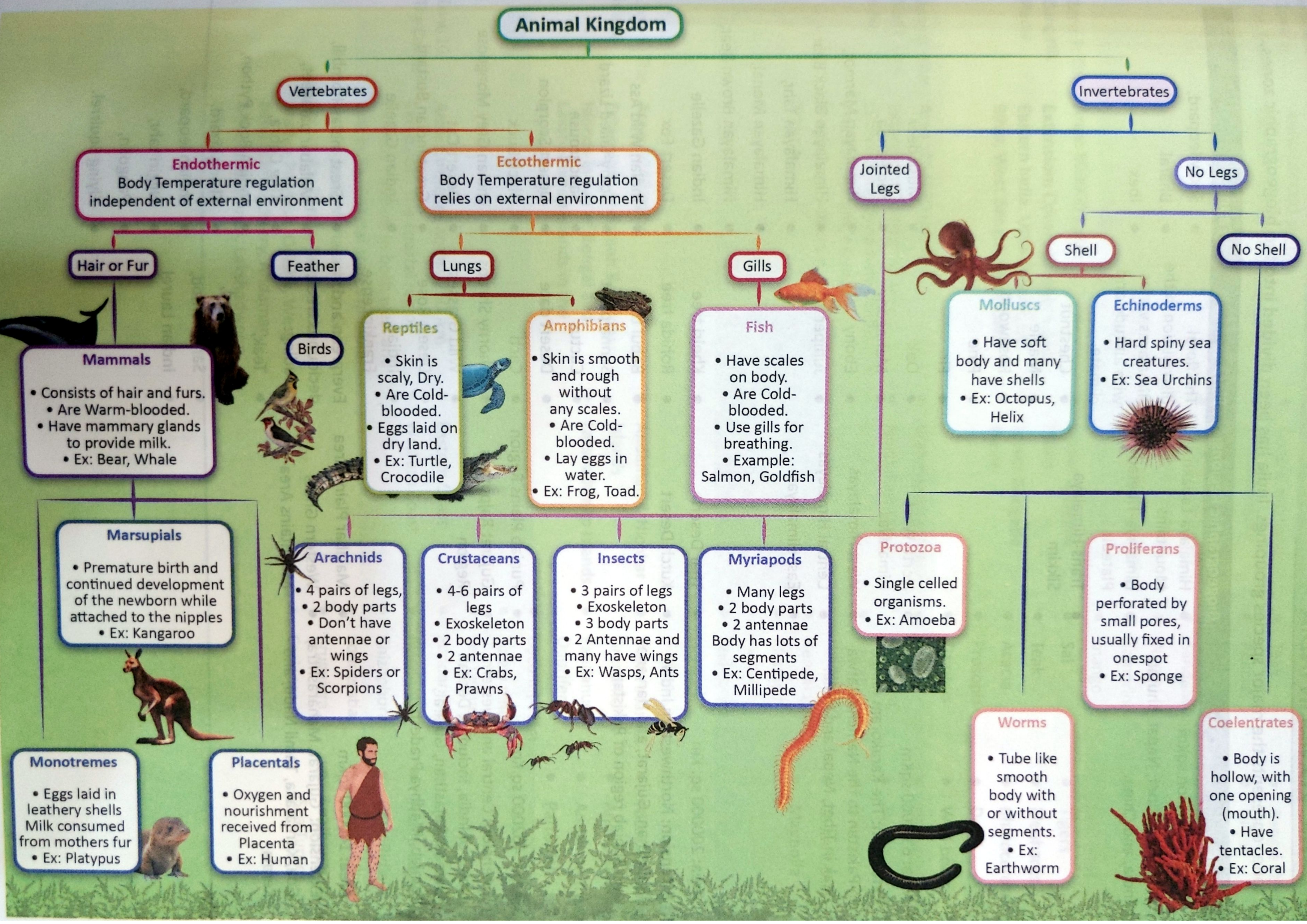
List of Important Endemic Faunal Species of India

Species	Habitat	Facts	Conservation Status		
			IUCN	CITES	WPA
Mammals					
Andaman White-toothed shrew 	Endemic to Andaman & Nicobar Islands	- Nocturnal animal - Live in sub-stratum of leaves in the forest - Eat insects	Critically Endangered	NA	NA
Jenkin's Andaman Spiny Shrew 	Endemic to Andaman & Nicobar Islands	NA	Critically Endangered	NA	NA

Species	Habitat	Facts	Conservation Status		
			IUCN	CITES	WPA
Nicobar White-tailed Shrew	Endemic to Great Nicobar	NA	Critically Endangered	NA	NA
Large Rock Rat or Elvira Rat 	Found only in Eastern Ghats of Tamil Nadu, India Appears to occur in rocky habitats and dry deciduous scrub forest at elevations of about 600m above mean sea level	- Its upper parts are brownish-grey and the underparts are greyish white. The tail is bicolored.	Critically Endangered	NA	NA
Malabar Civet 	Endemic to the Western Ghats of India	- It is nocturnal - Civetone is extracted from the scent gland of this animal and used in medicine and as an aromatic	Critically Endangered	Appendix III	Schedule I
Lion-tailed Macaque 	Endemic to Western Ghats of India	- It is diurnal arboreal - Prefers upper canopy of primary tropical evergreen rainforest	Endangered	Appendix I	Schedule I
Nilgiri Tahr 	Endemic to western ghats. Large population of Nilgiri Tahr is found in Eravikulam National Park.	- Locally known as 'Varaiaadu'. - The only mountain ungulate (animal with hooves). - State animal of Tamil Naidu. - It is adapted to both cold and wet tropical environments. - Threats: * Habitat Loss * Deforestation - It is conserved under the Project Nilgiri Tahar set up by the Tamil Nadu government.	Endangered	NA	Schedule I
Kolar Leaf Nosed Bat 	Endemic to India Found only in a cave in Hanumannahalli village in Kolar District of Karnataka	- A species of bat in the family of Hipposideridae - Threatened by illegal granite mining	Critically Endangered	Appendix I	NA
Kondana Rat 	Endemic to Sinhgad plateau, Maharashtra	- Nocturnal burrowing rodent - Threats are habitat loss, overgrazing, and tourism	Endangered	NA	NA

Species	Habitat	Facts	Conservation Status		
			IUCN	CITES	WPA
The Asiatic Lion 	Endemic to India Only found in the Gir National Park and in some parts of Gujarat.	- Smaller than African lions. - A longitudinal fold of skin runs along its belly which is absent in the African counterpart. - Males grow moderate manes as compared to the well-developed manes of African lions. - Depends on Chital, Nilgai, Sambhar, Buffaloes, and Goats for its diet. - threats: * Poaching * Habitat fragmentation * Genetic inbreeding	Endangered	Appendix I	Schedule I
Namdapha Flying Squirrel 	Endemic to Arunachal Pradesh	- It is an arboreal, nocturnal flying squirrel - Its crown is pale grey, its patagium is orangish and its underparts are white	Critically Endangered	NA	Schedule II
Sangai 	Found in Keibul Lamjao Park, Manipur	- The Sangai Festival is named after this deer. - Known for its distinctive antlers. - Called as the dancing deer. - Threats: * Loss of habitat *Invasion of non-native plants * Poaching Spreading of diseases from livestock animals.	Endangered	Appendix I	Schedule I
Nicobar Flying Fox 	Endemic to India	- Habitats are subtropical or tropical moist lowland forest and subtropical or tropical swamps	Endangered	NA	Schedule IV
Birds and Butterfly					
Forest Owlet 	South Madhya Pradesh, in north-west Maharashtra and north-central Maharashtra Only found in India	- Forest owlet is small and stocky - Unspotted crown and heavily banded wings and tail - Similar to spotted owlet	Endangered	Appendix I	Schedule I

Species	Habitat	Facts	Conservation Status		
			IUCN	CITES	WPA
Jerdon's Courser 	Eastern Ghats Endemic to Andhra Pradesh	- A nocturnal bird - It is a flagship species for the extremely threatened scrub jungle - Threats Clearing of scrub jungle, Creation of new pastures, Growing of dry land crop, Plantations of exotic trees, Quarrying and the construction of the Telugu-Ganga Canal	Critically Endangered	NA	Schedule I
Himalayan Quail 	Western Himalayas Tall grass and scrub on steep hillsides	- They are social birds and generally live in coveys of five to ten - Very rarely seen	Critically Endangered	NA	Schedule I
Southern Birdwing 	Endemic to South India	- One of the largest butterflies of India	Least Concern	NA	NA
Reptiles and Frog					
Jeypore Ground Gecko 	Endemic to peninsular India. Found in the eastern ghats, southern Odisha, and northern Andhra Pradesh.	- It is a nocturnal species. - Threats: * Habitat loss * Poaching	Endangered	Appendix II	Schedule 1
Sitana Visiri 	Endemic to Tamil Nadu, India	- It is also known as palm leaf fan-throated lizard - A species of agamid lizard	Vulnerable	NA	NA
Assam Keelback 	Endemic to Assam	- found after 129 years - non-venomous snake named after Samuel Peal	Data Deficient	NA	NA
Fish and Turtle					
Denison barb 	Endemic to Kerala and Karnataka	- A native freshwater fish species. - It inhabits fast-flowing hill streams. - It is also known as red-line torpedo barb, or roseline shark. - It is mostly exploited for the aquarium trade.	Endangered	NA	Schedule I
Leith's Soft-Shell Turtle 	Endemic to Peninsular India. Found in the ivers like Cauvery, Tungabhadra, Ghataprabha, Bhavani, Godavari, and Moyar.	- Large freshwater turtle. - Can grow up to 1 m in size. - Threats: * Used in traditional Chinese medicine * For soup delicacy	Critically Endangered	Appendix I	Schedule IV



Animal Kingdom

Vertebrates

Endothermic

Body Temperature regulation independent of external environment

Hair or Fur

Mammals

- Consists of hair and furs.
- Are Warm-blooded.
- Have mammary glands to provide milk.
- Ex: Bear, Whale

Marsupials

- Premature birth and continued development of the newborn while attached to the nipples
- Ex: Kangaroo

Monotremes

- Eggs laid in leathery shells Milk consumed from mothers fur
- Ex: Platypus

Placentals

- Oxygen and nourishment received from Placenta
- Ex: Human

Feather

Birds

Ectothermic

Body Temperature regulation relies on external environment

Lungs

Reptiles

- Skin is scaly, Dry.
- Are Cold-blooded.
- Eggs laid on dry land.
- Ex: Turtle, Crocodile

Amphibians

- Skin is smooth and rough without any scales.
- Are Cold-blooded.
- Lay eggs in water.
- Ex: Frog, Toad.

Gills

Fish

- Have scales on body.
- Are Cold-blooded.
- Use gills for breathing.
- Example: Salmon, Goldfish

Invertebrates

Jointed Legs

Arachnids

- 4 pairs of legs,
- 2 body parts
- Don't have antennae or wings
- Ex: Spiders or Scorpions

Crustaceans

- 4-6 pairs of legs
- Exoskeleton
- 2 body parts
- 2 antennae
- Ex: Crabs, Prawns

Insects

- 3 pairs of legs
- Exoskeleton
- 3 body parts
- 2 Antennae and many have wings
- Ex: Wasps, Ants

Myriapods

- Many legs
- 2 body parts
- 2 antennae Body has lots of segments
- Ex: Centipede, Millipede

No Legs

Shell

Molluscs

- Have soft body and many have shells
- Ex: Octopus, Helix

Echinoderms

- Hard spiny sea creatures.
- Ex: Sea Urchins

No Shell

Protozoa

- Single celled organisms.
- Ex: Amoeba

Worms

- Tube like smooth body with or without segments.
- Ex: Earthworm

Proliferans

- Body perforated by small pores, usually fixed in onespot
- Ex: Sponge

Coelentrates

- Body is hollow, with one opening (mouth).
- Have tentacles.
- Ex: Coral

BIOGEOGRAPHIC ZONES IN INDIA

Biogeographic zone represents the major species groupings. India has been **divided into ten biogeographic zones.**

Zones	Extent	Biogeographic Regions:	Flora	Fauna
Zone 1: The Trans Himalayas	**Area:** 2.5 million sqKm **Extension:** Tibet, Nepal, Bhutan, India, and China.	• Himalaya-Ladakh Mountains • Himalaya-Tibetan Plateau • Trans-Himalaya Sikkim	The floral distribution in the Himalayas varies with altitude and climate. • Chestnut • Maple • Rosewood • Pine • Fir	• Snow leopard, • Bharal • Ibex
Zone 2: The Himalayas	**Area:** 630,000 sqKm **Extension:** The Karakoram Range in Pakistan to the Namcha Barwa peak in Tibet, Nepal and India.	• North West Himalayas • West Himalayas • Central Himalayas • East Himalayas	• Oak • Mahagony • Ebony • Juniper	• Musk deer • Red Panda, • Himalayan Marmot, • Himalayan Black Bear • Himalayan Tahr, • Himalayan Monal, • Himalayan Brown Bear.
Zone 3: The Indian Desert	**Area:** 200000 sq. Km **Extension:** Northwestern India (Rajasthan, Gujarat, and Haryana) and Punjab region of Pakistan.	• Thar Desert • Kutch Desert	• Khejri tree • Rohida tree • Babul tree • Senna plant • Cactus • Desert date	• Indian Gazelle • Desert Fox • Indian Wild Ass • Spiny-tailed Lizard • Sandgrouse • Desert Scorpion
Zone 4: The Semi-Arid	**Area:** 462000 sq.Km **Extension:** Central and western states of India, including Deccan Plateau, Rajasthan, Gujarat, Punjab, Madhya Pradesh.	• Punjab Plains Region • Gujarat Rajputana Region	• Cacti • Thorny Shrubs • Wild Grasses • Desert Rose • Indian Frankincense	• Black Buck • Indian Grey Mongoose • Desert Cat • Great Indian Bustard • Indian Gazelle
Zone 5: The Western Ghats	**Area:** 140000 sqKm **Extension:** Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala.	• Malabar Plains Area • Western Ghats Mountains Area	Evergreen and deciduous trees, including: • Teak, • Rosewood, • Sandalwood, • Indian Laurel	• Great Indian hornbill, • Malabar parakeet, • King Cobra, • Indian Rock Python, • Flying Lizard. • Indian leopard, • Nilgiri tahr, • Pangolin, • Flying Squirrel.

Zones	Extent	Biogeographic Regions:	Flora	Fauna
Zone 6: The Deccan Peninsula	**Area:** 800000 sqKm **Extension:** Maharashtra, Goa, Karnataka, Andhra Pradesh, Tamil Nadu, Kerala.	• Central Highlands • Chhottanagpur Plateau • Eastern Highlands • Central Plateau • Deccan South Region	• Teak • Acacia • Eucalyptus • Sandalwood • Neem • Tamarind • mango	• Bengal Tiger • Nilgai • Wild boar • Indian cobra • Indian roller
Zone 7: The Gangetic Plains	**Area:** 800000 sqKm **Extension:** Covers Northern and Eastern India. Uttarakhand, UP, Bihar, West Bengal, Jharkhand	• Upper Gangetic Plains • Lower Gangetic Plains	• Sal • Teak • Acacia • Prosopis • Ziziphus	• Tigers • Elephants • Rhinoceroses • Deer • Wild boars
Zone 8: The North East India	**Area:** 262230 sqKm **Extension:** Consists of seven sisters of India, namely- Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura.	• Brahmaputra Valley • North East Hills	• Asiatic elephant • Indian rhinoceros • Bengal tiger • Clouded leopard • Red Panda • Hoolock Gibbon	• Dipterocarpus • Hopea • Shorea • Castanopsis • Magnolia
Zone 9: The Islands	**Area:** 8249 sqKm **Extension:** Andaman & Nicobar Islands in Bay of Bengal and Lakshadweep islands in the Arabian Sea.	• Andaman & Nicobar Islands • Lakshadweep Islands	• Dipterocarpus Grandiflorus • Pandanus Odorifer • Coconut Palm • Screw pine • Sea Lettuce	• Nicobar hornbill • Andaman dongo • Andaman treepie • Parrotfish
Zone 10: The Coasts	**Area:** Stretches across 7500km **Extension:** The coastal region extends 7500km in both west and east India. Coastal states of India are: Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha, West Bengal, Puducherry, Andaman & Nicobar Islands, Lakshadweep Islands.	• Eastern Coast • Western Coast	• Sundari tree, • Avicennia, • Rhizophora, • Sonneratia, • Bruguiera, • Ceriops	• Dugong • Hump-back Dolphin • Olive Ridley • Hawks Bill • Leather and Loggerhead Sea Turtles

BIODIVERSITY HOTSPOTS IN INDIA

Despite comprising just 2.4 percent of the earth's land area, India is home to 7-8 percent of the world's recorded species, and four of the 36 global biodiversity hotspots are located within its borders. The four biodiversity hotspots in India are the Himalayas, Indo-Burma (North-Eastern India and Andaman Islands), Sundalands (Nicobar Islands) and Western Ghats.

The Himalayas

- **Extent:** The Himalayas include Jammu and Kashmir, Himachal Pradesh, Uttarakhand, the northern region of West Bengal (Darjeeling), Sikkim, the northern portion of Assam and Arunachal Pradesh, as well as the parts of Pakistan, Tibet, Nepal, Bhutan, China, and Myanmar.
- **Species diversity and Endemism:** In terms of biogeography, the Himalayan Mountain range is situated in the transitional zone between the Palearctic and Indo-Malayan realms. As a result, the region encompasses species from both of these realms, making it a hotspot of biodiversity. The unique combination of the Himalayas' geographic location, physiography, climatic and altitudinal variations has contributed to a remarkable level of plant diversity and endemism in the area.
  - The Himalayan region is home to a diverse range of animal species, with over 300 mammal species (including 12 endemic and 4 threatened species), 977 bird species (with 15 endemics and 8 threatened species), 176 reptile species (of which 48 are endemics), and 105 amphibian species (with 40% endemism and 4 threatened species). Additionally, the region's freshwater ecosystems support 269 fish species, including 33 that are endemic to the hotspot area.
- **Flora:** Some of the major plant species found in Himalayan region are Himalayan blue poppy, Rhododendron, Himalayan Cedar, Himalayan Yew and Himalayan Cypress.
- **Fauna:** The hotspot is home to numerous animal species, like Snow leopard, Asiatic black bear, Red Panda, Himalayan Tahr, Musk deer, Takin, Bharal, Ibex, Himalayan Quail, Himalayan Monal.

Case Study: Environmental Issues in the Himalayan Region

Over the last 3-4 decades, the Himalayan region has faced several environmental issues, that have put pressure on its ecology, environment, composition, and biodiversity. Some of the important issues are:

- **Climate Change:** Its impact can be seen in the form of retreating glaciers in the Himalayan region. According to a report by the International Centre for Integrated Mountain Development (ICIMOD), glaciers in the Himalayas have been melting at an accelerating rate since the 1970s, with a loss of around 15% to 30% of glacial mass since the 1970s.

Important Glaciers that are melting at an alarming rate are:

- **Gangotri Glacier:** According to a report by the Geological Survey of India, the glacier has been retreating at a rate of around 22 meters per year.
- **Imja Glacier:** According to a study published in the journal Nature Climate Change in 2015, the glacier has been losing mass at a rate of around 0.5 meters per year.
- **Baltoro Glacier:** According to a study published in the journal Nature Geoscience in 2019, the glacier has been losing mass at a rate of around 1.2 meters per year.

According to the World Bank Report, the region's water resources are particularly vulnerable to climate change, and a 1°C increase in temperature could result in a 6-9% reduction in annual river flow.

In UN-backed research, it has been estimated that the melting glaciers in the Hindu Kush region will impact over two billion people in the form of food and water shortage.

- **Deforestation:** It has got intensified in the recent past due to population growth, industrialization, and unsustainable development in the region. According to a study published in the journal Nature in 2018, the Himalayan region lost more than 24,000 square kilometers of forest cover between 2000 and 2014. This represents a 3% decrease in forest cover over the 14-year period.
- **Forest Fires:** Due to the combination of natural and human-made factors, there is an increasing trend of forest fires in the Himalayan region. A report by the Forest Survey of India estimated that nearly 49,000 hectares of forest cover in the Indian Himalayas were affected by forest fires in 2020, which is a significant increase from the previous year.
- **Water Scarcity:** Due to the population boom, unsustainable development, and lack of awareness among the people, water resources are under immense pressure in the region. As per a report by ICIMOD, the Himalayan region is expected to experience alterations in water availability due to variations in precipitation patterns, timing and quantity of snow and glacier melt, and rising demand for water resources. A striking example of water scarcity in the Himalayan region is of Shimla Water Crisis 2018. Unsustainable urbanization, concretization, embarkment, and encroachments along with the unplanned and unmanageable footfall of tourism were the main reasons for the crisis.

- **Biodiversity Loss:** The Himalayan region along with being a biodiversity hotspot, is very fragile and vulnerable. According to a study published in the journal Biological Conservation in 2020, the Himalayan region has experienced a 43% decline in its vertebrate populations over the past 50 years, primarily due to habitat loss, degradation, and fragmentation caused by human activities such as deforestation, infrastructure development, and agriculture.
- **Air Pollution:** In the recent past, it has emerged as a major environmental issue mainly due to unregulated industrialization, unplanned expansion of transportation, and weak implementation of policies. A report released by the International Centre for Integrated Mountain Development (ICIMOD) in 2019 stated that the concentration of particulate matter (PM2.5) in the air in the Himalayan region exceeds the guidelines set by the World Health Organization (WHO).
- **Flash Floods:** These are a common occurrence in the Himalayan region which usually occur in the monsoon season due to the heavy rainfall. However, they have worsened due to human activities. For example, the 2013 flash flood in Kedarnath took over 6000 lives.
- **Landslides:** Due to the tectonic activities, the Himalayan region is prone to landslides, but in the recent past deforestation, hydropower projects, and construction of road and tunnels has made the situation bad to worse. According to the report of the Union Environment Ministry, landslides are responsible for nearly 50% of total disaster-related deaths in the region between 2005-2015.

Recent Example: The Joshi math Disaster

In January 2023, the Joshi math, in the Garhwal Himalayas in Chamoli District, Uttarakhand experienced massive land subsidence which led to cracks in hundreds of houses. According to the experts from various national and international agencies including the Geological Survey of India, it is the combination of factors, including

- **Location and Topography:** Joshi math is located on the middle slopes of a hill, bounded by four water bodies, making it a fragile location. The Mishra Commission report of 1976 identifies it as an unstable region due to ancient landslides and a thick layer of unstable material. The area has scattered gneissic rocks with low bearing capacity and loose soil, making it highly prone to landslides.
- **Seismic Activities:** According to the Seismic Map of India, Joshi math is located in Zone V of the Seismic Zonation Map and is very vulnerable to earthquakes.
- **Unplanned Development:** In the recent past, the region has witnessed rapid developmental activities such as hydropower projects like Vishnugad, construction of tunnels and roads by Border Road Organisation, which has led to disturbance in the region's ecology and stability.
- **Extreme Weather:** Frequent flooding have had a significant impact on the landslide zone, leading to extreme erosion. The latest satellite data shows that mountain streams have expanded their channels and changed their course, exacerbating the slope instability in an already fragile region.

Initiatives taken to Protect Himalayan Region

- **National Mission for Sustaining the Himalayan Ecosystem (NMSHE):** It was launched in 2010 by Indian government. Its goals include enhancing ecosystem resilience, promoting sustainable livelihoods, and addressing the impacts of climate change on the region.
- **WWF Conservation Program:** Launched in 1961, it aims to preserve the distinctive biodiversity of the Himalayan region while promoting sustainable development.
- **ICIMOD Research Program:** Launched in 2011, by International Centre for Integrated Mountain Development, it aims at researching the impact of climate change on the water resources of the Himalayan region.
- **Sustainable Agriculture and Forestry Practices:** Sustainable agriculture and forestry practices are being implemented by local communities and NGOs to promote sustainable development and protect the ecosystem. For instance, the Uttarakhand Biodiversity Board has initiated a project to promote sustainable farming practices and biodiversity conservation in the state.

The Indo-Burma Region

- ***Extent:*** The Indo-Burma biodiversity hotspot extends across several countries in Southeast Asia, including Myanmar, Thailand, Laos, Cambodia, Vietnam, and parts of southern China.
- ***Species diversity and Endemism:*** *The Indo-Burma region is a hotspot that combines different types of flora from various regions such as Indian, Malesian, Sino-Himalayan, and Indochinese, resulting in an exceptionally high diversity of plant species.*
  - There are estimated to be 15,000 to 25,000 plant species in the hotspot, half of which are unique to the area. 589 plant species in the hotspot are globally threatened.
  - The Indo-Burma hotspot is also home to numerous species of animals, such as 470 mammal species, 1,330 bird species, over 670 reptile species, more than 380 amphibian species, and 1,440 fish species.

- **Flora:** The Indo-Burma biodiversity hotspot is known for its exceptionally high plant species richness. About half of angiosperms and gymnosperms in the hotspot are endemic. The hotspot also contains many localized centers of endemism, particularly montane isolates, and also areas of lowland wet evergreen forest that were isolated at some stage, and river basins.
- **Fauna:** This hotspot is home to important populations of numerous animal species, like large-antlered muntjac, the Annamite muntjac, the grey-shanked douc, the Annamite striped rabbit, the leaf deer, the saola white-eared night-heron, the grey crowned crocias, and the orange-necked partridge.

The Sundaland

- **Extent:** The Sundaland biodiversity hotspot is bordered by three hotspots and is located in Southeast Asia. It encompasses parts of the Indonesian and Malaysian archipelagos, as well as parts of Brunei, Singapore, and the Philippines. The hotspot includes several major islands, such as Borneo, Sumatra, and Java, as well as numerous smaller islands.
- **Species diversity and Endemism:** Sundaland is one of the richest biodiversity hotspots, consisting of about 25,000 species of vascular plants, of which 15,000 species (60%) are exclusively confined to this hotspot.
- The hotspot is home to 117 endemic plants, of which 59 are found in Borneo, 17 in Sumatra, and 41 on the Malay Peninsula. Borneo has high level of tree diversity; there are about 3,000 tree species, including more than 265 species of dipterocarps, of which at least 155 are endemic to the island.
    - Notable plants in the hotspot include Rafflesia, represented by 16 species, including Rafflesia arnoldii, which produces the largest individual flower on earth, measuring up to one meter in diameter, and weighing about 7 kg.
    - Sundaland has six endemic bird areas, and the hotspot is home to 769 species of birds, of which 142 are endemic (18.5%) and 43 are globally threatened species. The hotspot supports 380 species of mammals, including 172 endemics (45.3%) and 60 threatened species, 452 reptile species with 243 endemics (53.8%), about 80% of amphibians (196 out of 244 species) are endemic and 59 species are threatened, and the freshwater ecosystems in the hotspot region support 950 species of fishes, of which 350 are endemic (36.8%).
- **Flora:** The lowland rainforests are mainly composed of tall trees from the Dipterocarpaceae family. Sandy and rocky coastlines have beach forests, while muddy shores have mangrove forests that extend inland to peat swamp forests. In some areas, ancient uplifted coral reefs support unique forests that can tolerate the high levels of calcium and magnesium in the soil. Infertile tertiary sandstone ridges have heath forests, while higher elevations have montane forests with moss, lichens, and orchids, and subalpine forests with rhododendrons.
- **Fauna:** The hotspot is home to iconic species like orangutans, pig-tailed langurs, Javan and Sumatran rhinos, and proboscis monkeys found only in Borneo.

The Western Ghats

- **Extent:** The Western Ghats, also known as the Sahyadri Mountains. The mountain range runs parallel to the western coast of India. It stretches from the southern tip of India in Tamil Nadu to the state of Gujarat in the north. The range is spread across six states of India - Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala.
- **Species diversity and Endemism:** The Western Ghats is one of the major tropical evergreen regions in India. It possesses exceptionally rich biodiversity owing to its climatic and geographic factors as well as its evolutionary continuity for more than 50 million years. Of the 15,000 flowering plant species in India, there are an estimated 4,780 species in the Western Ghats region. 439 species of the 5626 species of recorded Fauna are declared as endemic by the Zoological Survey of India. (ZSI).
- **Flora:** Some of the notable endemic plant species found in the Western Ghats include the Malabar Neem, Black Myrobalan, and Travancore Lady's Slipper Orchid. The region has a rich diversity of important tree species, including teak, rosewood, and sandalwood.
- **Fauna:** The Western Ghats are home to a diverse range of mammal species, including several large mammals such as the Bengal Tiger, Indian Elephant, Indian Bison (Gaur), and Sloth Bear. The region also has many smaller mammals such as the Lion-tailed Macaque, Nilgiri Langur, and Malabar Giant Squirrel. The region has many endemic bird species such as the Malabar Grey Hornbill, Nilgiri Flycatcher, the White-bellied Treepie, the Indian Pitta, Black-and-orange Flycatcher, and the Nilgiri Thrush.

Case Study: Environmental Issues in the Western Ghats

- **Deforestation:** According to the report of the Ministry of Environment, Forest and Climate Change, the Western Ghats region witnessed a net loss of over 16,000 square kilometers of forest cover between 1920 and 2014. The primary causes of this loss are agricultural expansion, logging, mining, infrastructure development, and urbanization.
- **Biodiversity Loss:** Unsustainable development with rapid industrialization and unregulated mining activities in the Western Ghats has caused destruction of natural habitats of species.
- According to a report by the International Union for Conservation of Nature (IUCN), 132 species of plants and animals in the Western Ghats are classified as critically endangered, endangered, or vulnerable.
- **Human-Animal Conflicts:** Due to the habitat loss and shrinking of water bodies and food resources, the animal finds their way toward the human population, which is intensifying the frequency of confrontation between humans and animals. According to a study by the Wildlife Conservation Society, the Western Ghats region has the highest number of human-wildlife conflict incidents in India. Among these conflicts, Elephants contribute the maximum with 60% of total conflicts.
- **Illegal Mining:** Western Ghats is a resource-rich area and significant minerals such as iron ore, manganese, bauxite, and limestone are found here, which are used in different industries such as steel, cement, and construction. Despite the declaration of the western ghats as an Ecological Sensitive Zone and the ban on mining activities, the Supreme Court and CAG have observed major mining activities throughout the Western Ghats. According to newspaper reports, Maharashtra alone reported recorded 1,39,706 illegal mining cases from 2013 to 2017.
- **Forest Fires:** According to a study published in the journal Current Science, the frequency of forest fires in the Western Ghats has increased over the past few decades, with an average of 6,000 hectares of forest land being affected by fires annually. For example, in 2018, a major forest fire broke out in the Bandipur Tiger Reserve in Karnataka, which destroyed over 2,000 hectares of forest land and threatened the wildlife in the area.
- **Invasive Species:** They pose a significant threat to the biodiversity of the Western Ghats as they can disrupt natural ecosystems, displace native plant and animal species, and cause ecological imbalances. A study published in the journal Biological Invasions identified multiple invasive plant species in the Western Ghats, including Lantana camara, Eichhornia crassipes, and Mikania micrantha causing the displacement of native plant species and the modification of natural ecosystems.
- **Climate Change:** The Indian Network on Climate Change Assessment (INCCA) has reported that the Western Ghats region of India is likely to face rising temperatures, alterations in precipitation patterns, and an elevated frequency of extreme weather events, such as floods, droughts, and landslides.

Eco-Sensitive Zone in the Western Ghats

To protect the rich biodiversity of flora and fauna in the Western Ghats, the Union Environment Ministry declared the Western Ghats as an Eco-Sensitive zone in 2010 under the Environment Protection Act of 1986. According to the notification, an area of approximately 60,000 square kilometers across six states in India, including Kerala, Tamil Nadu, Karnataka, Maharashtra, Goa, and Gujarat came under the Eco-sensitive zone.

To properly propose and demarcate the boundaries of ESZ in Western Ghats, two important reports were formed in India, namely Gadgil Committee and Kasturirangan Committee.

Comparison of Both Committees

Parameter	Gadgil Committee	Kasturirangan Committee
Name	Western Ghats Ecology Expert Panel (WGEEP) report	High-Level Working Group (HLWG) report
Year	2011	2013
Division	Divided western ghats into three categories of ESZs based on vulnerability and restriction imposed. *ESZ1*- Highly Sensitive area *ESZ2*- moderate Sensitive area *ESZ3*- Less Sensitive area	Divided the entire Western Ghats into two categories namely, Natural and Cultural landscapes **Natural**- High Ecological sensitivity **Cultural**- Low Ecological sensitive
Extent	*It declared the entire Western Ghats as Eco-sensitive Zone.*	Declared only **37%** of the Natural landscape as Eco-sensitive Zone.
Determination of ESZs	At the block/taluka level.	At the Village level
Restriction	*Red and Orange category Industries*	**Only Red Category Industries**

INITIATIVES FOR BIODIVERSITY CONSERVATION

Biodiversity Conservation is the preservation, protection, management, or restoration of wildlife and natural resources such as forests and water. It becomes imperative to conserve biodiversity because of the immense significance it holds in terms of genetic diversity, commercial potential, medical breakthroughs, aesthetic appeal, and ecological balance.

INITIATIVES FOR BIODIVERSITY CONSERVATION GLOBAL

Stockholm Conference

It was the UN's first major conference on international environmental issues organized in 1972

- **Theme in 1972:** 'Only One Earth'
- **Participation**: 122 countries adopted the Stockholm Declaration
- **Key outcomes of the conference:**
    - Countries agreeing not to harm each other's environment
    - Action plan to study the threat to Earth's environment
    - Establishment of UN Environment Programme (UNEP)

Organizations tracing their origin to Stockholm Conference

- Most of the conventions related to planetary crises like the United Nations Framework Convention on Climate Change (UNFCCC), **the Convention to Combat** Desertification (UNCCD), **and the** Convention on Biological Diversity (CBD) **etc. have their origin in the** Stockholm Declaration

Stockholm+50

The meeting was held **at Stockholm in June 2022,** Sweden to commemorate **the 50 years United Nations** Conference on the Human **Environment, 1972.**

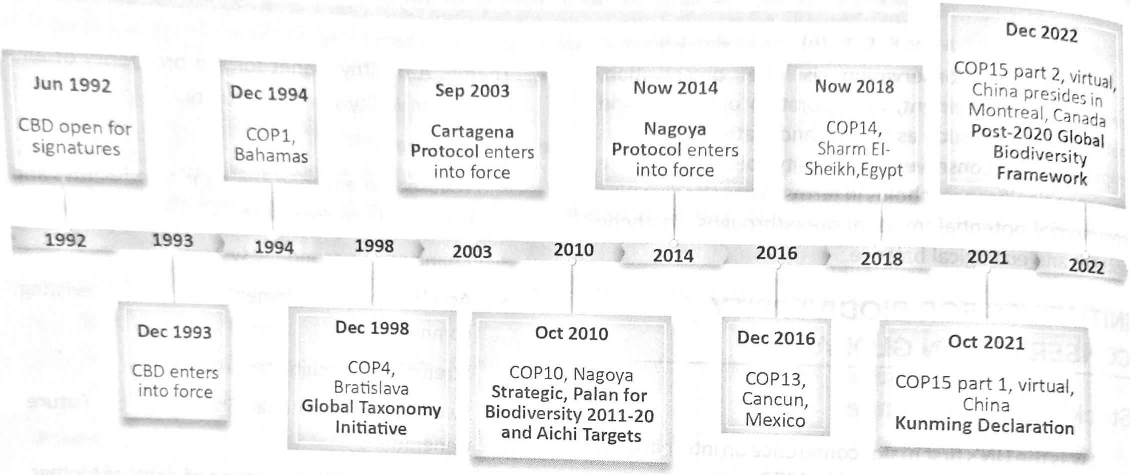
- **Theme**: A healthy planet for the prosperity of all – our responsibility, our opportunity
- **Key Outcomes**
    - Focused on ensuring the right to a healthy and sustainable environment
    - Changing our economic system
    - Accelerating implementation of existing commitment
    - Strengthening multilateralism
    - Sweden-led Ministerial Statement on Future Generations
    - Petition for a UN declaration of rights of Mother Earth, a Youth Task Force declaration

United Nations Convention on Biological Diversity (CBD)

It is the most important global environmental treaty on conservation of biodiversity. It seeks to address the accelerating biodiversity loss and its potential impact on sustainable development and human well-being. The treaty is legally binding.

- **Background:** The UN CBD builds upon the principles put forward in the World Conservation Strategy (1980) and the Brundtland Report (1987), which emphasized upon sustainable use and conservation of biodiversity. The CBD was adopted during the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992.
- **Headquarters and Membership:** The CBD is headquartered in Montreal, Canada. Currently, 196 countries, including India, are party to the CBD. The United States of America (USA) has not ratified the Convention.
- **Goals:** There are three main goals of the Convention:
    - Conservation of Biological Diversity

  - Sustainable Use of Biodiversity
  - Fair and Equitable Sharing of Benefits arising from the utilization of genetic resources.
- **National Strategies and Biodiversity Action Plans (NSBAPs):** NSBAP is the chief instrument of implementing the CBD at national levels. The countries party to the Convention are encouraged to develop and implement these plans. The plans act as roadmaps for integrating biodiversity conservation into national policies, programs, and decision-making processes.


Jun 1992
CBD open for signatures
Dec 1994
COP1, Bahamas
Sep 2003
Cartagena Protocol enters into force
Now 2014
Nagoya Protocol enters into force
Now 2018
COP14, Sharm El-Sheikh,Egypt
Dec 2022
COP15 part 2, virtual, China presides in Montreal, Canada
Post-2020 Global Biodiversity Framework
1992
1993
1994
1998
2003
2010
2014
2016
2018
2021
2022
Dec 1993
CBD enters into force
Dec 1998
COP4, Bratislava
Global Taxonomy Initiative
Oct 2010
COP10, Nagoya
Strategic, Palan for Biodiversity 2011-20 and Aichi Targets
Dec 2016
COP13, Cancun, Mexico
Oct 2021
COP15 part 1, virtual, China
Kunming Declaration

Timeline of the Convention on Biological Diversity

Biodiversity Finance Initiative (BIOFIN)

Launched in 2012, it is a global partnership led by the United Nations Development Programme (UNDP) that assists governments in funding, planning, and financing biodiversity conservation and sustainable use efforts.

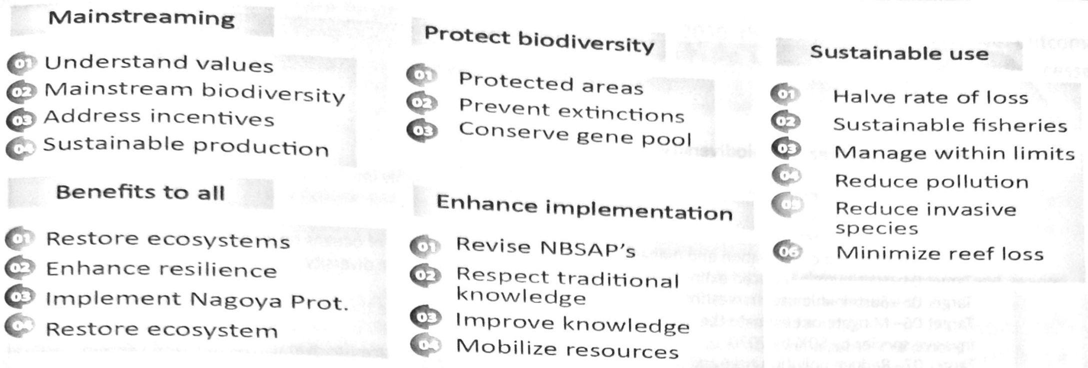
- **Objectives:**
  - It focuses on supporting the development of comprehensive national resource mobilization strategies at the country level.
  - It provides recommendations to help countries identify financing mechanisms, including considerations such as institutional requirements, laws and regulations, taxes and fees.
  - It also focuses on setting legal thresholds, eliminating incentives harmful to biodiversity, conducting feasibility studies and implementation plans, establishing certification processes, fostering public-private partnerships, and promoting voluntary agreements.

Significance: BIOFIN helps in the implementation of the National Biodiversity Action Plans and achieve the national biodiversity targets.

Note: In India, the MoEFCC leads the BIOFIN.

Aichi Biodiversity Targets

These are a set of strategic goals and objectives aimed at addressing global decline of biodiversity and ecosystems. The targets were adopted as part of the Strategic Plan for Biodiversity 2011-2020 during the 10th meeting of the Conference of the Parties (COP) to the CBD held in Aichi Prefecture, Japan, in 2010.



Mainstreaming

- 01 Understand values
- 02 Mainstream biodiversity
- 03 Address incentives
- 04 Sustainable production

Benefits to all

- 01 Restore ecosystems
- 02 Enhance resilience
- 03 Implement Nagoya Prot.
- 04 Restore ecosystem

Protect biodiversity

- 01 Protected areas
- 02 Prevent extinctions
- 03 Conserve gene pool

Enhance implementation

- 01 Revise NBSAP's
- 02 Respect traditional knowledge
- 03 Improve knowledge
- 04 Mobilize resources

Sustainable use

- 01 Halve rate of loss
- 02 Sustainable fisheries
- 03 Manage within limits
- 04 Reduce pollution
- 05 Reduce invasive species
- 06 Minimize reef loss

Aichi Biodiversity Targets

According to the **Global Biodiversity Outlook 5 report** published by the United Nations in 2020, none of the Aichi biodiversity targets have been achieved at a global level. Out of the twenty goals, only six were partially achieved, 38 showed progresses while 13 showed no progress.

The failure of the Aichi Targets could be attributed to:

- **Inadequate funding**: The financial resources allocated to biodiversity conservation, especially in the developing countries were insufficient to effectively address the scale of the challenges.
- **Weak implementation and enforcement:** Many countries performed poorly at implementation and enforcement of biodiversity conservation measures at the national level.
- **Inadequate monitoring and reporting**: There have been a lack of robust monitoring, planning, reporting and review framework. This made it difficult to assess the actual progress and identify loopholes.

CoP 15 of the United Nations Convention on Biodiversity

The 15th Conference of Parties (CoP15) of the Convention on Biological Diversity concluded in Montreal, Canada in 2022. It was held in two phases: Phase I in October 2021 in Kunming, China and Phase II in December 2022 in Montreal, Canada. The theme for COP15 was "Ecological Civilization: Building a Shared Future for All Life on Earth". The conference sought to adopt a Global Biodiversity Framework (GBF), which will replace the Aichi Biodiversity Targets that expired in 2020.

Major Outcomes of CoP 15 to the UN CBD

- **Adoption of Kunming-Montreal Global Biodiversity Framework (GBF):** It consists of four long-term goals for 2050 and 23 targets to be achieved by 2030 to halt and reverse global biodiversity loss. Its cornerstone is the target to conserve 30% of the world's land and 30% of the world's oceans by 2030, widely known as the **30×30 pledge.** It is **non- legally binding.**
- **Global Biodiversity Framework Fund (GBF Fund):** The Global Environment Facility (GEF) was requested to establish a "Special Trust Fund" – called the Global Biodiversity Framework Fund (GBF Fund) – "in 2023, and until 2030" to support the Global Biodiversity Framework.
- **Multilateral fund on Digital Sequence Information (DSI):** Within GBF, a multilateral fund for the equitable sharing of benefits between providers and users of digital sequence information on genetic resources (DSI) to be established.
- **Adoption of Gender Plan of Action:** It aims to support and promote the gender responsive implementation of the Global Biodiversity Framework.
- **Monitoring and reporting progress:** National action plans will be set and reviewed, following a similar format used for greenhouse gas emissions under U.N.-led efforts to curb climate change.

The High Ambition Coalition (HAC) for Nature and People

It is an intergovernmental group of more than 100 countries co-chaired by Costa Rica and France and by the United Kingdom as Ocean co-chair. It makes a global deal for nature and people with the central goal of protecting at least 30 percent of the world's land and ocean by 2030.

23 targets of Kunming- Montreal Global Biodiversity Framework to be achieved by 2030

(A) Reducing threats to biodiversity

Target 01– Effective management of land- and sea-use change, loss of highly important biodiverse areas close to zero by 2030
Target 02– Effective restoration of 30% of degraded ecosystems by 2030
Target 03– Effective conservation and management of 30% of land and 30% of oceans by 2030
Target 04– Halt human-induced extinctions and maintain and restore genetic diversity
Target 05– Sustainable use, harvesting and trade of wild species
Target 06– Mitigate or eliminate the impacts of invasive alien species, reduce the rates of establishment of invasive species by 50% by 2030
Target 07– Reduce pollution risks and impacts from all sources by 2030, reduce the overall risk from pesticides by half
Target 08– Minimise the impacts of climate change and ocean acidification on biodiversity

(B) Meeting people's needs through sustainable use and benefit-sharing

Target 09– Ensure sustainable use and management of wild species, while protecting customary use by Indigenous peoples
Target 10– Sustainable management of areas under agriculture, aquaculture, fisheries and forestry
Target 11– Restore and enhance ecosystem function through nature-based solutions and ecosystem-based approaches
Target 12– Increase the area and quality of urban green and blue spaces
Target 13– Fair and equitable sharing of the benefits arising from the use of genetic resources

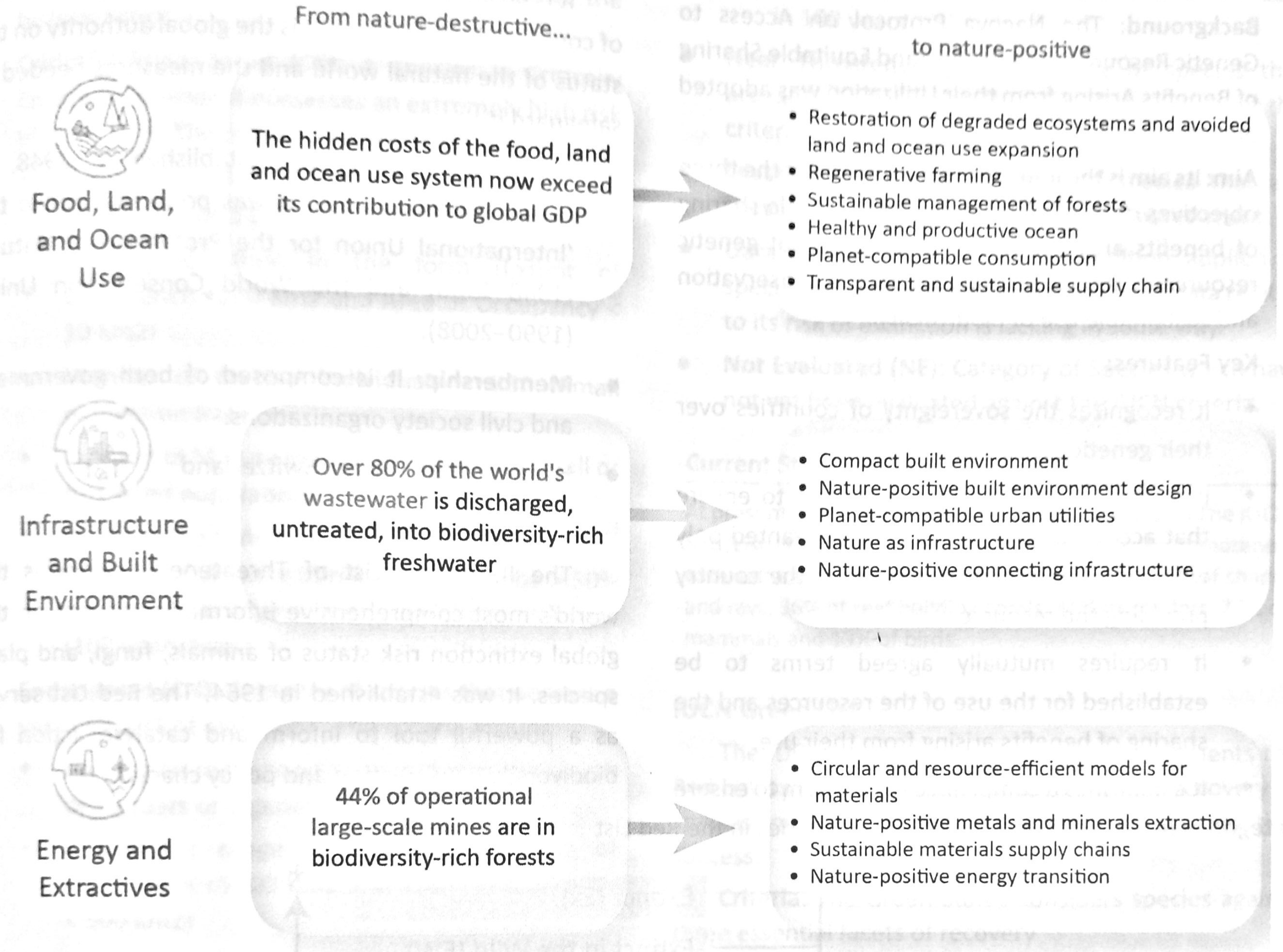
(C) Tools and solutions for implementation and mainstreaming

Target 14– Integration of biodiversity into policies and development across all sectors
Target 15– Enable businesses to monitor, assess and disclose their impacts on biodiversity
Target 16– Encourage sustainable consumption, including by reducing food waste by half by 2030
Target 17– Strengthen capacity for biosafety measures and ensure benefits-sharing from biotechnology
Target 18– Phase out or reform harmful subsidies in a just way, reducing them by $500bn by 2030
Target 19– Substantially increase financial resources, mobilise $200bn per year by 2030 from all sources, including $30bn from developed to developing countries
Target 20– Strengthen capacity-building and technology transfer
Target 21– Integrated and participatory management, including the use of traditional knowledge
Target 22– Equitable representation and participation of Indigenous peoples and local communities
Target 23– Ensure gender equality in the implementation of the framework

From Nature Destructive to Nature Positive

Concept of Nature Positive: Being nature positive means halting and reversing current trends of ecological destruction. The main idea is that there should be more nature in 2030 than 2020. Nature-positive outcomes involve the protecting and restoring natural processes, ecosystems and species.

How to achieve Nature Positive?


From nature-destructive...
to nature-positive
Food, Land, and Ocean Use
The hidden costs of the food, land and ocean use system now exceed its contribution to global GDP
• Restoration of degraded ecosystems and avoided land and ocean use expansion
• Regenerative farming
• Sustainable management of forests
• Healthy and productive ocean
• Planet-compatible consumption
• Transparent and sustainable supply chain
Infrastructure and Built Environment
Over 80% of the world's wastewater is discharged, untreated, into biodiversity-rich freshwater
• Compact built environment
• Nature-positive built environment design
• Planet-compatible urban utilities
• Nature as infrastructure
• Nature-positive connecting infrastructure
Energy and Extractives
44% of operational large-scale mines are in biodiversity-rich forests
• Circular and resource-efficient models for materials
• Nature-positive metals and minerals extraction
• Sustainable materials supply chains
• Nature-positive energy transition

Supplementary Agreements of the CBD

There are several supplementary agreements to the CBD. These agreements provide additional guidance and mechanisms for implementing specific aspects of the Convention. Notable supplementary agreements include: a. Cartagena Protocol on Biosafety and the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization.

Cartagena Protocol

The Cartagena Protocol on Biosafety is an international agreement that aims to ensure the safe handling, transport, and use of living modified organisms (LMOs) resulting from modern biotechnology.

- **Background:** The protocol was adopted on January 29, 2000, and entered into force on September 11, 2003.
- **Membership:** As of 2021, the protocol has been ratified by 171 countries.
- **Key Features:**
  - The protocol establishes a framework for the risk assessment and management of LMOs, as well as measures to promote public awareness and participation in decision-making related to biotechnology.
  - It requires countries to regulate the import, export, and transit of LMOs in accordance with established procedures.
  - The procedure requires exporters to provide information about the LMOs they intend to export.

- It establishes a **Biosafety Clearing-House.** It is an online mechanism for exchanging information and promoting cooperation between countries on issues related to biosafety.

Nagoya Protocol

- **Background**: The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization was adopted on October 29, 2010, in Nagoya, Japan.
- **Aim:** Its aim is the implementation of one of the three objectives of the CBD: the fair and equitable sharing of benefits arising out of the utilization of genetic resources, thereby contributing to the conservation and sustainable use of biodiversity.
- **Key Features:**
  - It recognizes the sovereignty of countries over their genetic resources
  - It requires parties to take measures to ensure that access to genetic resources is granted only with the prior informed consent of the country providing the resources
  - It requires mutually agreed terms to be established for the use of the resources and the sharing of benefits arising from their use.
  - It establishes a compliance mechanism to ensure that parties comply with their obligations under the agreement.

International Union for Conservation of Nature (IUCN)

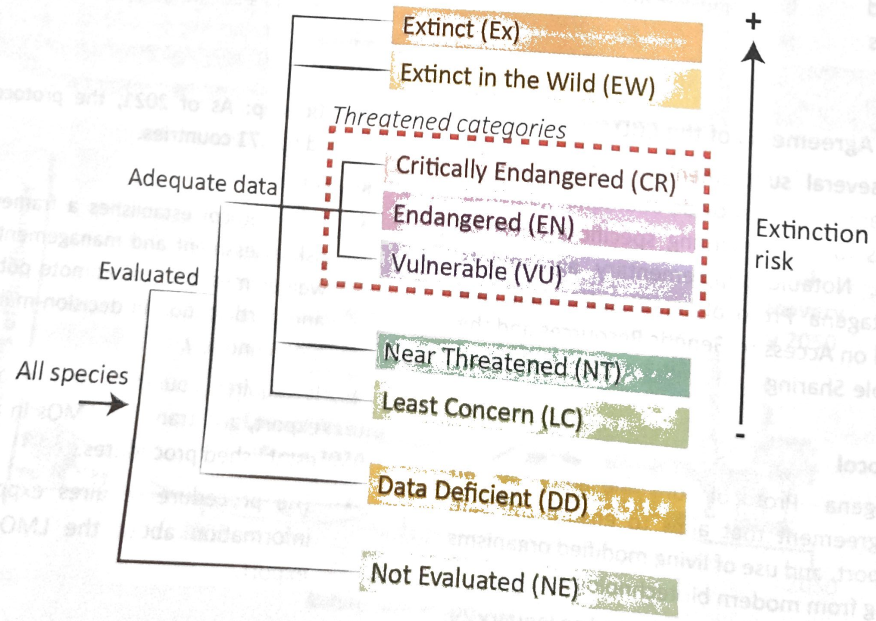
It is an international organization working in the field of conservation of nature. It is the global authority on the status of the natural world and the measures needed to safeguard it.

- **Background:** IUCN was established in 1948, in Fontainebleau, France. It was previously called the 'International Union for the Protection of Nature' (1948–1956) and the World Conservation Union (1990–2008).
- **Membership**: It is composed of both government and civil society organizations.
- **Headquarters**: Gland, Switzerland

IUCN Red List of Species

The IUCN Red List of Threatened Species is the world's most comprehensive information source on the global extinction risk status of animals, fungi, and plant species. It was established in 1964. The Red List serves as a powerful tool to inform and catalyze action for biodiversity conservation and policy change.

Categories in the Red List: There are 9 categories in the Red List



IUCN

- **Extinct (EX):** A species is considered to be extinct when here is no reasonable doubt that the last individual has died.
- **Extinct in Wild (EW):** A species is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population outside the historic range.
- **Critically Endangered (CE):** A species is Critically Endangered when it possesses an extremely high risk of extinction. The criteria include:
    - Population reduction (measured over the length of 10 years or 3 generations) is > 90%
    - Geographic range in the form (Extent of Occurrence <100 Km2 and Area of Occupancy < 10 Km2)
    - Number of mature individuals < 250 (Small population size)
    - Number of Mature individuals < 50 (very small or restricted population)
    - Quantitative Analysis i.e., indicating the probability of extinction in the wild to be > 50% in 10 years or 3 generations, whichever is longer (100 years max.)
- **Endangered (EN):** Category of species that possess a very high risk of extinction. The criteria include:
    - Population reduction (measured over the length of 10 years or 3 generations) is > 70%
    - Geographic range in the form (Extent of Occurrence <5000 Km2 and Area of Occupancy < 500 Km2)
    - Number of mature individuals < 2500 (Small population size)
    - Number of Mature individuals < 250 (very small or restricted population)
    - Quantitative Analysis i.e., indicating the probability of extinction in the wild to be > 20% in 20 years or 5 generations, whichever is longer (100 years max.)
- **Vulnerable (VU):** Category of species that possess a high risk of endangerment. The criteria include:
    - Population reduction (measured over the length of 10 years or 3 generations) is > 50%
    - Geographic range in the form (Extent of Occurrence <20,000 Km2 and Area of Occupancy < 2000 Km2)
    - Number of mature individuals < 10,000 (Small population size)
    - Number of Mature individuals < 1000 (very small or restricted population)
    - Quantitative Analysis i.e., indicating the probability of extinction in the wild to be > 10% in 100 years
- **Near Threatened (NT):** Category of species that are close to becoming threatened or may meet the criteria for threatened status in the near future.
- **Least Concern (LC):** Category of species that are pervasive and abundant after careful assessment
- **Data Deficient (DD):** It is a condition applied to species in which the amount of available data related to its risk of extinction is lacking in some way.
- **Not Evaluated (NE)**: Category of Species which have not yet been evaluated against the IUCN criteria.

Current Status of the IUCN Red List

At present, there are more than 150,300 species on The IUCN Red List. There are more than 42,100 species threatened with extinction, including 41% of amphibians, 37% of sharks and rays, 36% of reef building corals, 34% of conifers, 27% of mammals and 13% of birds.

IUCN Green List

The IUCN Green Status of Species complements the Red List by providing a tool for assessing the recovery of species' populations and measuring their conservation success.

Criteria: The Green Status considers species against three essential facets of recovery

- A species is fully recovered if it is present in all parts of its range, even those that are no longer occupied but were occupied prior to significant human impacts/ disruption.
- It is viable (i.e., not threatened with extinction) in all parts of the range.
- It is performing its ecological functions in all parts of the range.

Management Effectiveness Tracking Tool (METT)

It is a tool developed by IUCN to assess and monitor the effectiveness of protected area management. It helps evaluate how well-protected areas are being managed and identifies areas for improvement.

It assesses protected areas based on a set of criteria that cover different aspects of management effectiveness. These criteria include

- **Context:** This criterion looks at the legal and policy framework, as well as the social, economic, and political context in which the protected area operates.
- **Planning and Design:** It assesses the quality and effectiveness of the protected area's management plan, including its objectives, zoning, and stakeholder involvement.
- **Inputs:** This criterion evaluates the availability and adequacy of resources, such as funding, staff, infrastructure, and equipment, necessary for effective management.
- **Processes:** It examines the implementation of management activities, including enforcement, monitoring, research, community engagement, and capacity building.
- **Outputs:** This criterion assesses the achievement of management objectives and the delivery of conservation outcomes, such as the status of biodiversity, ecosystem services, and the fulfillment of societal needs.
- **Outcomes:** It evaluates the long-term impacts of management actions on the protected area's ecological, social, and economic values.

Nature-based Solutions (NBS)

Nature-based Solutions is an ecological approach that include actions or policies that harness the power of nature to address important societal challenges, for example, threats to water security, rising risk of disasters, or climate change. The idea of NBS was pioneered by IUCN. The Global Standard for Nature-based Solutions has also been developed by IUCN.

- ***Scope of NBS***: *NBS involves protection, restoration, and sustainable management of ecosystems in ways that increase their resilience and make them better equip to address the societal challenges. These solutions not only preserve biodiversity but also enhance the well-being of people.*
- ***Examples of Nature based Solutions***
    - ***Natural Flood Management:*** *Implementing measures like reforestation, wetland restoration, and creating buffer zones along rivers.*
    - ***Stormwater Management***: *Construction of green roofs, rain gardens, or constructed wetlands.*

    - **Prevention of Coastal Erosion:** Restoration or creation of natural coastal habitats such as mangroves, dunes, or seagrass beds.

The Save Our Species (SOS)

It is a funding program established by the International Union for Conservation of Nature (IUCN). It aims at securing the long-term survival of endangered species, their habitats, and the communities reliant on them. It was founded in 2010 by IUCN, Global Environment Facility (GEF), and World Bank.

Convention in International Trade in Endangered Species of Wild Fauna and Flora (CITES)

CITES is an international agreement aimed at regulating and monitoring the trade of endangered species of wild animals and plants. It plays an important role in ensuring the sustainable utilization and conservation of global biodiversity.

- **Background:** CITES emerged against the backdrop of increasing concerns regarding the escalating rate of wildlife trafficking and the consequential threat to biodiversity. The United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN) jointly initiated discussions in the early 1970s. CITES was signed in 1973, and finally came into force in 1975.
- **Objectives:** The main objectives of CITES are as follows:
    - **Regulation:** It seeks to ensure that international trade in specimens of wild animals and plants does not threaten their survival.
    - **Conservation**: It aims to promote the conservation of endangered species by regulating trade and preventing overexploitation.
    - **Sustainable Utilization:** It seeks to promote sustainable trade that is ecologically sound and economically viable.
- **Parties to Convention:** 184 parties, including India.
- **Nature:** CITES is legally binding on the parties. However, it does not take the place of national laws.

CITES Listing

CITES Listing

APPENDIX I	*It lists species which are most endangered* *They are threatened with extinction and CITES prohibits international trade in specimens of these species except when the purpose of the import is not commercial, for instance for scientific research*

CITES Listing	
APPENDIX II	• It lists the species that are not threatened with extinction but may become so if trade is not controlled. • It also includes so-called "look-alike species", i.e., species whose specimens in trade look like those of species listed for conservation reason
APPENDIX III	• It is a list of species that are included at request of Parties which already regulate trade in those species & that needs cooperation of other countries to prevent illegal exploitation. • International trade in specimens of species listed in this Appendix is allowed only on presentation of the appropriate permits or certificates.

COP 19 of CITES

The 19th meeting of the Conference of Parties to Convention on International Trade in Endangered Species of wild fauna and flora (CITES) was held Panama in November 2022.

Major Outcomes of COP 19 of CITES

- **Inclusion of Shisham Tree:** It was included in Appendix II. CITES also relaxed restrictions on the export of furniture and handicrafts made of shisham from India.
- **Inclusion of Indian Turtle Species:** Red-crowned roofed turtles and Leith's soft-shell turtle were included in Appendix I.
- **Inclusion of Jaypore Ground Gecko:** It was listed in Appendix II. The reptile is endemic to India and found in Eastern Ghats. **(IUCN Status- Endangered)**
- **Inclusion of Songbirds: White Rumped Shama** was added to Appendix II. **Straw-headed bulbul** was moved from Appendix II to Appendix II.
- **Others:** 104 shark and ray species consisting of Hammerhead sharks, Guitar fish and Requiem sharks like the Blue Shark and three Indo-Pacific Sea cucumbers and various marine species were included in Appendix II.
- **Take on Ivory:** India decided not to vote against a proposal to re-open the international trade in ivory which was banned in 1989.

Convention on the Conservation of Migratory Species of Wild Animals (CMS)

Also known as the Bonn Convention, CMS is an international treaty, under the aegis of the United Nations Environment Programme, established in 1979. It is the only global organization established exclusively for the conservation and management of terrestrial, aquatic and avian migratory species throughout their range.

- **Members:** 130 States (including India) and the EU
- **Objectives:**
  - **Conserve migratory species**: It seeks to ensure the survival and well-being of migratory species throughout their entire range.
  - **Promote international cooperation**: It promotes international collaboration among its member countries through exchange of scientific research, technical information, and best practices.
  - **Facilitate species conservation agreements**: It facilitates the development and implementation of legally binding agreements, known as Memoranda of Understanding (MoUs), for specific migratory species or groups of species.
- **There are two Appendices:**
  - **Appendix I** – Threatened migratory species: It includes migratory species threatened with extinction
  - **Appendix II** – Migratory species requiring international cooperation- It includes migratory species that need or would significantly benefit from international co-operation.

India and CMS:

Since 1983, India has been a party to the CMS. India has signed Memorandum of Understanding (MoU) with CMS on Siberian Cranes, Marine Turtles, Dugongs and Raptors. India has also signed the Central Asian Flyway Action Plan.

Central Asian Flyway (CMF)

The Central Asian Flyway is one of eight major migratory bird flyways recognized globally. It falls under the purview of Convention on the Conservation of Migratory Species of Wild Animals (CMS).

- **Extent:** It covers a large continental area of Eurasia between the Arctic and Indian Oceans and the associated island chains. It connects the breeding grounds of birds in the Arctic tundra of Siberia to their wintering grounds in South Asia, Southeast Asia, and Australia. Geographically the flyway region covers 30 countries of North, Central and South Asia and Trans-Caucasus.

- **Significance:** The CAF covers at least 279 populations of 182 migratory water bird species, including 29 globally threatened and near-threatened species. CAF Action Plan has played a significant role in the conservation of migratory species such as the Bar-headed Goose, Anser indicus, Indian Skimmer, Siberian crane, Sociable lapwing, etc.

Central Asian Mammals Initiative (CAMI)

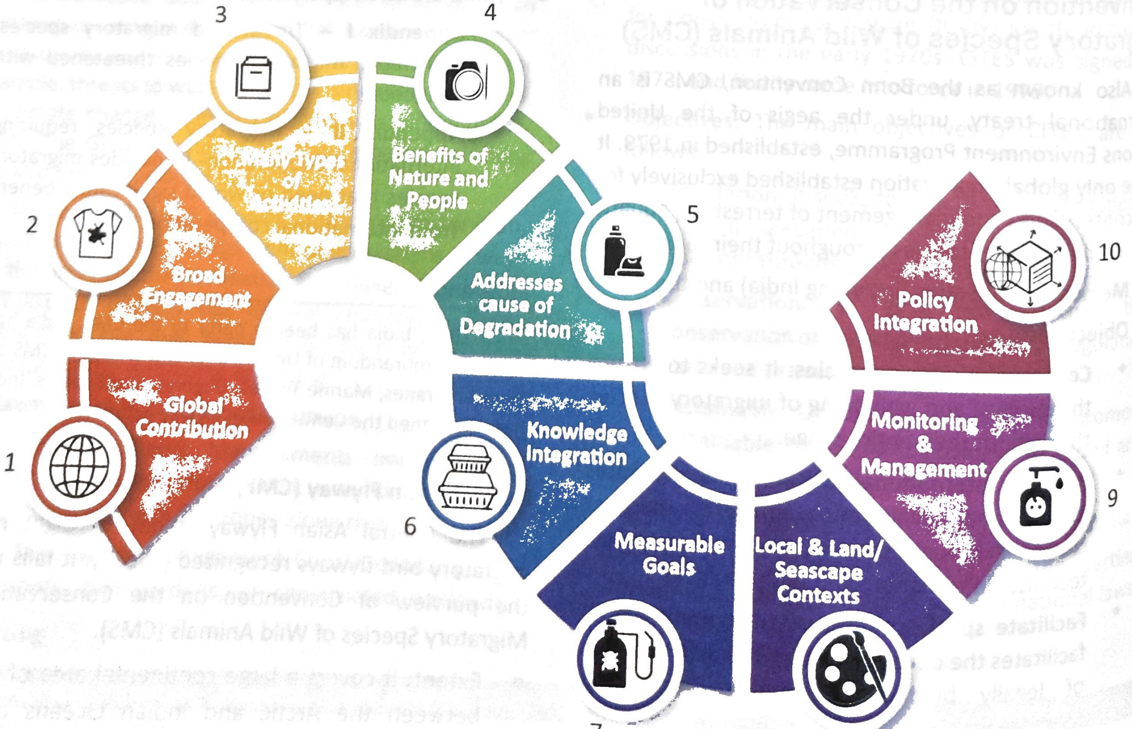
It is regional programme created under the CMS. It aims to reverse the population decline of 15 migratory mammal species in 14 Central Asian countries where these species live. Some of the species under CAMI include the snow leopard, saiga antelope, Pallas's Cat, Goitered Gazelle and Bactrian camel.

CAMI's operations have been authorized for the period of 2021-2026. It will also incorporate the Central Asia initiative of IUCN Save Our Species programme as a potential funding mechanism for conserving critically threatened migratory species.

World Restoration Flagships

These are the first, best, or most promising examples of large scale and long-term **ecosystem restoration** in any country, embodying the **10 Restoration Principles of the UN Decade.**

- **Selection Criteria:**
    - Clearly identifiable geography
    - Part of nominated area already under successful, measurable, and well-documented restoration
    - Well-defined short-, medium-, and long-term ecological, cultural, and socio-economic objectives and goals.
- **Monitoring:** Their progress will be monitored through the Framework for Ecosystem Restoration Monitoring- the UN Decade's platform for keeping track of global restoration efforts.
- **Benefit:** Initiatives declared World Restoration Flagships are eligible to receive UN-backed promotion, advice or funding.



United Nations Decade on Ecosystem Restoration

It is a global movement coordinated by the **United Nations Environment Programme (UNEP) and the United Nations Food and Agriculture Organization (FAO).** It aims to revive billions of hectares, covering terrestrial as well as aquatic ecosystems. It is designed to prevent and reverse the degradation of natural spaces across the planet. The United Nations General Assembly (UNGA) proclaimed **2021–2030** as the **Decade on Ecosystem Restoration.**

The 10 inaugural World Restoration Flagships' List

The 10 flagships stretch across 23 countries and cover all ecosystems. These 10 flagships will restore more than 68 million hectares. They will create some 15 million jobs.

Flagship Initiative	Countries	Details
Trinational Atlantic Forest Pact	Argentina, Brazil, Paraguay	**Aim:** To restore South America's iconic Atlantic Forest **Initiative of:** The Pact for the Restoration of the Atlantic Forest and the Trinational Network for the restoration of the Atlantic Forest.
Great Green Wall for Restoration and Peace	Burkina Faso, Djibouti, Eritrea, Ethiopia, Mali, Mauritania, Niger, Senegal, Sudan, Chad	**Aim:** To restore savanna, grasslands and farmlands across Sahel region. **Initiative of:** Pan-African Great Green Wall Agency, Initiative of the Great Green Wall for the Sahara and the Sahel Burkina Faso, UNEP Finance Initiative etc.
Namami Gange	India	**Aim:** To rejuvenate India's sacred Ganges River and surrounding basin and restore people's connection to the river, while reducing pollution and reversing deforestation. **Initiative of:** National Mission for Clean Ganga under the Government of India, and supported by the World Bank, the Japan International Cooperation Agency and the German Development Agency.
Abu Dhabi Marine Restoration	United Arab Emirates	**Aim:** To restore coral, mangrove and seagrass in Abu Dhabi, creating a refuge for the dugong, a fast-disappearing aquatic mammal. **Initiative of:** The Environment Agency – Abu Dhabi
Small Island Developing States	Vanuatu, Comoros, Saint Lucia	**Aim:** To restore sensitive ecosystems in Vanuatu, St. Lucia and Comoros and help the island nations safeguard wildlife, brace for climate change and strengthen their Economies. **Initiative of:** Governments of Comoros, Saint Lucia, and Vanuatu, The Small Island Developing States Coalition for Nature, The United Nations Department of Economic and Social Affairs, FAO and UNEP
Atlyn Dala Conservation Initiative	Kazakhstan	**Aim:** To conserve and restore Kazakhstan's steppe, semi-desert and desert ecosystems across the historical range of the Saiga antelope. **Initiative of:** Association for the Conservation of Biodiversity of Kazakhstan, Frankfurt Zoological Society etc.
Central American Dry Corridor	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama	**Aim:** To restore 300,000 ha of drought-stricken Central American farmland and forests. **Initiative of:** Central American Commission on Environment and Development, Green Climate Fund, IUCN etc.
Building with Nature in Indonesia	Indonesia	**Aim:** To naturally regenerate mangroves and protect Indonesia's coast against Flooding. **Initiative of:** Indonesian Ministry of Marine Affairs, Wetlands International etc.

Flagship initiative	Countries	Details
Shan-Shui Initiative in China	China	**Aim:** To restore 10 million hectares of ecosystems across China, including forests, grasslands and waterways. **Initiative of:** Ministry of Natural Resources and Ministry of Finance, People's Republic of China.
Multi-country Mountain Flagship	Democratic Republic of the Congo, Kyrgyzstan, Rwanda, Serbia, Uganda	**Aim:** To protect mountain landscapes in Kyrgyzstan, Rwanda, Uganda and Serbia and to safeguard a range of imperiled species, including mountain gorillas and snow leopards. **Initiative of:** The United Nations Environment Programme, The Mountain Partnership, and The Carpathian Convention

Wildlife Trade Monitoring Network (TRAFFIC)

TRAFFIC, known as the Wildlife Trade Monitoring Network, is a prominent non-governmental organization (NGO) focused on wildlife trade within the realms of biodiversity conservation and sustainable development. It operates as a collaborative initiative between the World Wildlife Fund (WWF) and the International Union for Conservation of Nature (IUCN). It was established in 1976 and is headquartered in Cambridge, United Kingdom

- **Objective**
- The primary objective of TRAFFIC is to safeguard nature conservation by ensuring that the trade of wild plants and animals does not pose a threat.
- It strives to mitigate the negative impacts of wildlife trade and promote sustainable practices.

TRAFFIC and India

Since 1991, TRAFFIC has functioned as a Programme Division of WWF-India, headquartered in New Delhi. Current projects of TRAFFIC in India include studies on leopard and tiger poaching and trade, peacock feather trade, owl trade, hunting community dynamics, medicinal plant trade, bird trade, and more.

World Wildlife Fund for Nature, Inc (WWF)

It is an international non-governmental organization that works in the field of wilderness preservation and the reduction of human impact on the environment.

- **Background:** It was founded in 1961. It was previously known as World Wildlife Fund.
- **Priority Areas:** The WWF's work is centered around six priority areas for improved environmental management comprising climate, forests, food, freshwater, wildlife and oceans.
- **Major Initiatives and Publications**
  - **Debt-for-nature swaps**: These are financial transactions in which a portion of a developing nation's foreign debt is forgiven in exchange for local investments in environmental conservation measures.
  - **Earth Hour:** It is an annual effort of the World Wildlife Fund for Nature (WWF) that began in 2007. It is held annually on last Saturday of March. It urges individuals in over 180 nations to turn off their lights between 8.30 p.m. and 9.30 p.m. local time. It is an attempt to promote conservation of energy.
  - **Living Planet Report**: It is a comprehensive study of trends in global biodiversity and the health of the planet. It is published every two years and is based on the Living Planet Index and ecological footprint calculations.

Coalition Against Wildlife Trafficking (CAWT)

CAWT is a unique coalition consisting of governments and organizations that voluntarily come together to address the issue of wildlife trafficking. It is a US led coalition against wildlife trafficking that was launched in 2004.India is a member of CAWT.

Objectives

- Strengthen wildlife law enforcement through regional cooperation, training, and information sharing.
- Gain political support for effective measures against illegal wildlife trade to foster strong political will.
- Increase consumer awareness about the negative impacts of wildlife trade on biodiversity, environment, livelihoods, and health.
- Emphasize the connection between wildlife trafficking and organized crime while promoting sustainable alternatives to reduce consumer demand for illegal wildlife.

Birdlife International

It is a global partnership of conservation organizations dedicated to the preservation of birds, their habitats, and global biodiversity. It is recognized as the world's largest conservation partnership focused on the protection of birds and their habitats.

- **Background:** It was founded in 1922 as the International Council for Bird Protection
- **Headquarters**: It operates through its global office in the UK and maintains six regional offices across Africa, the Americas, Asia, Europe and Central Asia, the Middle East, and the Pacific.
- **Functions**
    - The partnership publishes a quarterly magazine called **World Birdwatch**, which provides up-to-date news and authoritative articles on birds, their habitats, and conservation efforts worldwide.
    - It serves as the official Red List authority for birds within the International Union for Conservation of Nature (IUCN), contributing to the assessment and classification of bird species based on their conservation status.
    - The partnership has published an inventory known as the **Important Bird Areas (IBA),** which identifies key locations worldwide that are crucial for bird conservation.

International Whaling Commission (IWC)

It is an intergovernmental organization established in 1946 with the goal of conserving whale populations and promoting the sustainable management of whaling activities.

- **Objectives:** The main objectives of IWC are:
    - To ensure the long-term conservation and recovery of whale species.
    - To regulate and control commercial and scientific whaling activities to ensure their sustainability and prevent further depletion of whale stocks.
    - To encourage and facilitate research on whale biology, ecology, and population dynamics.
- **Members:** It has current membership of 88 governments. India became a member of the IWC in 1981.
- **The convention recognizes three different types of whaling**
    - **Commercial Whaling:** It is regulated by commission by commercial whaling moratorium which was adopted in 1982 banned commercial whaling
    - **Aboriginal Subsistence Whaling:** Commission regulates this Whaling which is conducted by indigenous communities recognizing their nutritional and cultural needs
    - **Special permit (Scientific) Whaling:** It is not regulated by the Commission but by respective national governments

International Consortium on Combating Wildlife Crime (ICCWC)

Established in 2010, it is a collaborative partnership to enhance international efforts to combat wildlife crime.

- **Members:** Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Secretariat, INTERPOL, the United Nations Office on Drugs and Crime (UNODC), the World Bank, and the World Customs Organization (WCO).
- **Goal:** It aims to strengthen the enforcement of laws related to wildlife crime so that the use of natural resources is sustainable, benefiting both people and the environment.

INITIATIVES FOR BIODIVERSITY CONSERVATION INDIAN

Biological Diversity Act in 2002

Background: India enacted Biological Diversity Act in 2002 for giving effect to the provisions of the CBD.

Aim: To promote the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of biological resources and knowledge.

Key Features of the Act

- **Regulation of access of biological resources:** The Act regulates the requests for access to the biological resources as well as transfer of information of traditional knowledge to foreign nationals, institutions and companies.
- **National Plans and Programmes:** The Act makes the central government duty-bound for formulating national strategies, plans and programmes to

conserve and uphold the sustainable use of biological diversity.

- **Conservation of Threatened Species:** The Central government is empowered to notify threatened species and prohibit or regulate their collection, rehabilitation and conservation.
- **Biodiversity Heritage Sites**: The State Government in consultation with local bodies may notify areas of biodiversity importance as Biodiversity Heritage Sites (BHS).
- **Authorities:** The Act provides for the establishment of National Biodiversity Authority (NBA) at the national level, State Biological Board (SBB) at state level and Biodiversity Management Committees (BMC's) at local levels.

National Biodiversity Action Plan (NBAP)

National Biodiversity Authority

- **Headquarters**: Chennai
- **Headed by**: Chairperson:
- **Functions:**
  - Regulation of acts prohibited under the Act
  - Advise the Government on the conservation of biodiversity
  - Advise the Government on selection of biological heritage sites
  - Take appropriate steps to oppose the grant of intellectual property rights in foreign countries, arising from the use of biological resources or associated traditional knowledge
- **Offences:** The offences under the Act are cognizable and non-bailable.

India became a Party to the CBD in 1993, and prepared its first NBAP entitled "National Policy and Macro Level Action Strategy on Biodiversity" in 1999. The Strategy, 1999 was revised and updated into NBAP, 2008 to bring the biodiversity agenda in alignment with the National Environment Policy, 2006. It was further updated in 2014 to integrate the Strategic Plan for Biodiversity 2011-20 which included the Aichi Biodiversity Targets. There are 12 National Biodiversity Targets (NBTs)

Wildlife Protection Act, 1972

It was enacted considering that all previous laws such as the Wild Birds and Animals Protection Act, 1912 were insufficient. It aims to protect and conserve the wildlife in India

Key Features:

- **Scope of Protection:** The act protects all kinds of animals from amphibians to birds, mammals, and reptiles.
- **Classification of Animals in Different Schedules:**
  - Before, the 2022 Amendment, the Act provided for 6 schedules. Each schedule gave a varied form of protection.
  - Schedule 1 and Schedule 2 provided absolute protection to the wild animals and for the violation of such provisions the penalty charged was very high.
  - In Schedule 3 and Schedule 4 animals were protected here but the penalty charged was low.
  - Schedule 5 stated the list of animals (vermin) which could be hunted.
  - Schedule 6 stated the list of specified endemic plants which are prohibited for cultivation and planting.
- **Director of Wildlife and Chief Wildlife Warden**
  - The Central Government is empowered to appoint the Director of Wildlife Preservation
  - The State Government is required to appoint the Chief Wildlife Warden, Wildlife Wardens, and Honorary Wildlife Wardens
- **Prohibition on Hunting:** It prohibits hunting of wild animals except in certain cases such as education and research or if a wild animal is threat to human life or diseased/disabled beyond recovery.
- **Establishment of Protected Areas:** The Act provides for the establishment of protected areas viz. sanctuaries, national parks, conservation reserves, community reserves and tiger reserves.
- **Trade and commerce:** The states that the wild animals are property of the Government. It prohibits the trade in trophies, animals, and animal articles from wild animals other than vermin.
- **Constitution of the National Board for Wildlife**
  - The Wildlife (Protection) Amendment Act, 2002, constituted the National Board for Wildlife
  - The Prime Minister is the chairperson of the National Board of Wildlife.
  - The board functions to promote the conservation and development of wildlife and forest.
  - It can also frame policies and advise the central and the state governments on ways and means of promoting wildlife conservation

The Wildlife (Protection) Amendment Act, 2022

Key features of the Amendment Act	
About	• The Act amends Wild Life (Protection) Act, 1972 • Aim: To strengthen the protection of endangered species and enhance punishment for illegal wildlife trade.
Implementation of CITES	• The amendment act seeks to give effect to India's obligations under the CITES, which requires countries to regulate trade of all listed specimens through permits.
	Obligations under CITES
	• The Act provides for the central government to designate a **management Authority**, which grants **export or import permits** for trade of specimens under CITES. • Every person engaging in trade of a scheduled specimen must report the details of the transaction to the Management Authority. • As per CITES, the Management Authority may use an identification mark for a specimen. The Act prohibits any person from modifying or removing the identification mark of the specimen. • Additionally, every person **possessing live specimens** of scheduled animals must obtain a registration certificate from the Management Authority.

Key features of the Amendment Act

Rationalizing schedules

Earlier	Now
The WPA, 1972 has **six schedules** for specially protected plants (one), specially protected animals (four), and vermin species (one).	The Act **reduces** the total number of schedules to **four** which includes the **removal** of schedule for **vermin species,** and **insertion** of a new schedule for specimens under **CITES.**

Invasive alien species

- The Act empowers the central government to regulate or prohibit the import, trade, possession or proliferation of invasive alien species.
- Invasive alien species refers to plant or animal species which are not native to India and whose introduction may adversely impact wild life or its habitat.

Surrender of captive animals

- The Act provides for any person to voluntarily surrender any captive animals or animal products to the Chief Wild Life Warden.
- No compensation will be paid to the person for surrendering such items. The surrendered items become property of the state government.

Conservation reserves

Earlier	Now
Under the WPA 1972, **state governments** may declare areas adjacent to national parks and sanctuaries as a **conservation reserve**, for protecting flora and fauna, and their habitat.	The Act empowers the **central government** to **also** notify a conservation reserve.

Control of sanctuaries:

Earlier	Now
• The WPA 1972, entrusts the Chief Wildlife Warden to control, manage and maintain all sanctuaries in a state.	• The Act specifies that actions of the Chief Warden must be in accordance with the management plans for the sanctuary. • These plans will be prepared as per guidelines of the central government, and as approved by the Chief Warden.

Penalties

The Act **increases the fines** for violating the provisions of the Act.

Type of Violation	1972 Act	2022 Act
General violation	Up to Rs 25,000	Up to Rs 1,00,000
Specially protected animals	At least Rs 10,000	At least Rs 25,000

Animal Welfare Board

The Animal Welfare Board of India is a statutory body established in 1962 under Section 4 of The Prevention of Cruelty to Animals Act, 1960. Initially under the jurisdiction of the Ministry of Food and Agriculture, the Board was later transferred to the Ministry of Environment and Forests in 1990. The headquarters of the board was shifted from Chennai, Tamil Nadu to Ballabhgarh in Faridabad District of Haryana.

Objective

- Its primary focus is to ensure compliance with animal welfare laws and it also grants funds to Animal Welfare Organizations.
- As an advisory body, it provides recommendations to the Government of India on animal welfare laws and actively promotes animal welfare throughout the country.

Function

- The Animal Welfare Board formulates rules and regulations to ensure humane treatment of animals in various settings and has been actively involved in legal advocacy to strengthen animal protection laws.

National Action Plan for Conservation of Migratory Birds

The National Action Plan for the Conservation of Migratory Birds (2018-2023) was introduced with the aim of addressing the population decline of migratory birds and safeguarding their habitats.

Implementation

- The plan's implementation period spans from 2018 to 2023, during which targeted efforts will be made to achieve the plan's objectives.

- The Ministry of Environment, Forest and Climate Change is responsible for overseeing the implementation of the plan.

Objective

- The primary objective of the plan is to halt the decline in the population of migratory birds by the year 2027.

Components of the plan

The plan consists of six components to achieve its objectives:

- **Species conservation**: Protect migratory birds by identifying critical habitats, involving local communities, and addressing threats like hunting and poaching.
- **Habitat management:** Conserve and manage vital habitats such as wetlands, forests, and grasslands to sustain migratory bird populations.
- **Communication and outreach**: Raise awareness among policymakers, communities, and the public about the importance of migratory birds and their habitats.
- **Capacity development:** Enhance the abilities of government agencies, NGOs, and local communities to implement the plan effectively.
- **Research and knowledge base**: Improve understanding of migratory birds and their conservation needs through research and monitoring.
- **International cooperation:** Foster collaboration among countries along the Central Asian Flyway to protect migratory birds and their habitats.

Integrated Development of Wildlife Habitat (IDWH)

It is a Centrally Sponsored Scheme that has been implemented by expanding the scope of the previous scheme called "Assistance for the Development of National Parks and Sanctuaries" during the 11th Plan Period. It aims to provide financial assistance to State/ UT Governments for the protection and conservation of wildlife and their habitats, both within and outside Protected Areas (PAs).

- The scheme also supports recovery programs for critically endangered species.
- IDWH includes additional components and activities to enhance the effectiveness of wildlife habitat conservation efforts.

Wildlife Crime Control Bureau

It was established in 2007 under the Wildlife Protection Act 1972, recognizing the gravity of organized wildlife Crime and illicit trade of wildlife parts and products. It operates as a legally mandated, statutory body under the Ministry of Environment, Forest and Climate Change (MoEFCC). It operates through its headquarters in Delhi, along with regional offices in Kolkata, Mumbai, Chennai, and Jabalpur.

- **Functions**
    - It serves as the central agency responsible for enforcing CITES regulations.
    - The bureau shares this intelligence with state and other enforcement agencies to aid in the apprehension of criminals involved in wildlife crimes.
    - The WCCB maintains a centralized wildlife crime data bank and coordinates actions among various agencies to enforce the provisions of the Act.
    - It collaborates with international organizations and foreign authorities to facilitate wildlife crime control.
    - The WCCB provides advice to the Government of India on matters pertaining to wildlife crimes.
    - The bureau supports and advises Customs authorities in inspecting consignments of flora and fauna in compliance with the provisions of the Wild Life Protection Act, CITES, and the EXIM Policy.

India's Species Recovery Programme

It aims to conserve 16 terrestrial and 6 aquatic species to ensure their protection outside Protected Areas, across the wider landscape/seascape.

Species Covered under the Programme

- Asian Wild Buffalo
- Asiatic Lion
- Brow-Antlered Deer or Sangai
- Dugong
- Edible Nest Swiftlet
- Gangetic River Dolphin
- Great Indian Bustard
- Hangul
- Indian Rhino or Great One-horned Rhinoceros
- Jerdon's Courser

- Malabar Civet
- Marine Turtles
- Nicobar Megapode
- Nilgiri Tahr
- Snow Leopard
- Swamp Deer
- Vultures
- Northern River Terrapin
- Clouded Leopard
- Arabian Sea Humpback Whale
- Red Panda
- Caracal

National Wildlife Action Plan (NWAP)

The Nation Wildlife Action Plan (2017-2031) was released by MoEFCC in 2017. It aims at the preservation of genetic diversity and sustainable development. The NWAP has five components, 17 themes, 103 conservation actions and 250 projects.

- **Five Key components:**
  - Strengthening and promoting the integrated management of wildlife and their habitats;
  - Adaptation to climate change and promoting integrated sustainable management of aquatic biodiversity in India;
  - Promoting eco-tourism, nature education and participatory management;
  - Strengthening wildlife research and monitoring of development of human resources in wildlife conservation
  - Enabling policies and resources for conservation of wildlife in India.

Botanical Survey of India

It is an apex research institute of India for documenting and conserving the plant wealth of India, that works under the Ministry of Environment, Forest and Climate Change.

Evolution: *It was established in 1890 under the Indian Forest Act of 1865 by the colonial Government and was initially known as the "Imperial Forest Research Institute". Then in 1914, its name was changed to the "Forest Research Institute and Botanical Survey of India" to reflect its dual role in forest research and botanical exploration. After Independence, it was recognized by* Indian Government in 1954, and finally, its name was changed to the Botanical Survey of India.

The mandate of the Botanical Survey of India

Primary

- To Explore, and Document the phytodiversity (including non-flowering plants) in India;
- Publication of National, State, and District flora.
- Identification of Red list species and other species-rich areas that are in need of conservation;
- Ex-situ conservation through botanical gardens.
- Survey and documentation of traditional knowledge (ethnobotany) associated with plants.
- Develop a National database of Indian plants, including herbarium specimens, live specimens, botanical paintings, illustrations, etc.

Secondary

- Revisionary/Monographic studies on selected plant groups.
- Develop fresher courses and post-M.Sc. certificate courses to develop capacity in plant taxonomy.
- Conducting Environment Impact Assessment of the areas assigned to BSI for study.
- Develop and maintain Botanical Gardens, Museums, and Herbaria.
- Preparation of Seed, Pollen, and Spore Atlas of Indian Plants.

Zoological Survey of India

It is a premier organization to document and conduct studies regarding faunal species of India. It was established on 1st July 1916 by the colonial Government and presently it works under the Ministry of Environment, Forest and Climate Change.

Primary Objectives:

- Conduct exploration, survey, inventorying, and monitoring of faunal diversity in different states, ecosystems, and protected areas of India.
- Conduct taxonomic studies on all collected faunal components.
- Regularly review the status of threatened and endemic species.
- Prepare Red Data Book, Fauna of India, and Fauna of States publications.
- Conduct bioecological studies on selected important communities and species.

- Create and maintain databases for recorded species in the country.
- Preserve and develop the National Zoological Collections.
- Provide training, capacity building, and human resource development opportunities.
- Offer faunal identification, advisory services, and library services.
- Publish research findings, including Fauna of India and Fauna of States.

Secondary Objectives:

- Conduct environmental impact studies.
- Maintain and develop museums at headquarters and regional stations.
- Establish ENVIS (Environmental Information System) and CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) centers.
- Facilitate research fellowship, associateship, and emeritus scientist programs.
- Foster collaborative research programs on biodiversity with other organizations

Green Good Deeds Initiative

It is a social initiative launched by MoEFCC in 2018. The aim of the initiative is to foster environmental awareness and engage people from all sections of society in conserving the environment throughout the country. It focuses on practical and straightforward actions that individuals in India can incorporate into their daily lives to protect and preserve the environment.

- The **National Green Corps Program**, a part of the scheme, has set up approximately 150,000 eco clubs in schools, colleges, and universities nationwide. Over 3.5 million students have actively taken part in the program.